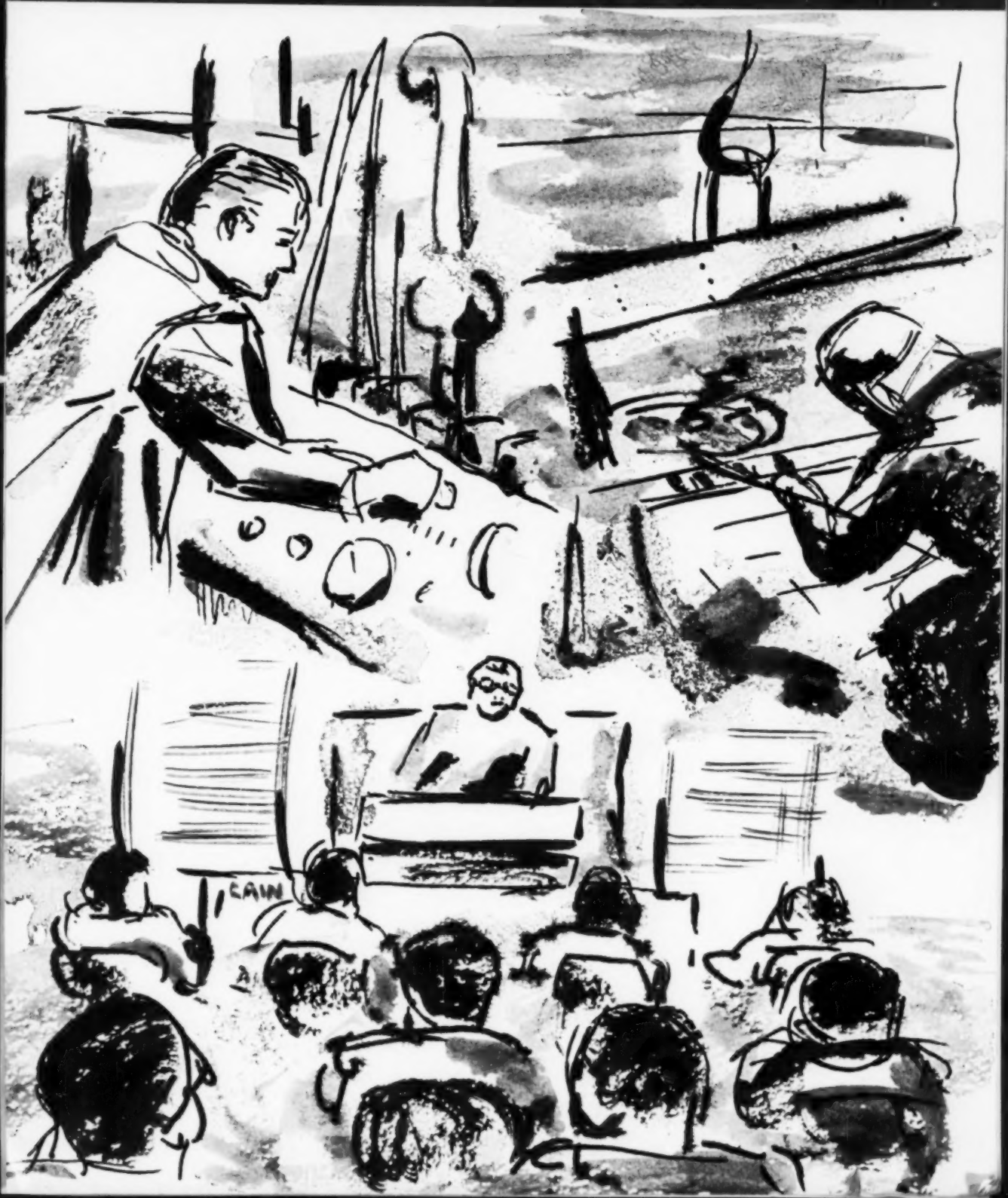
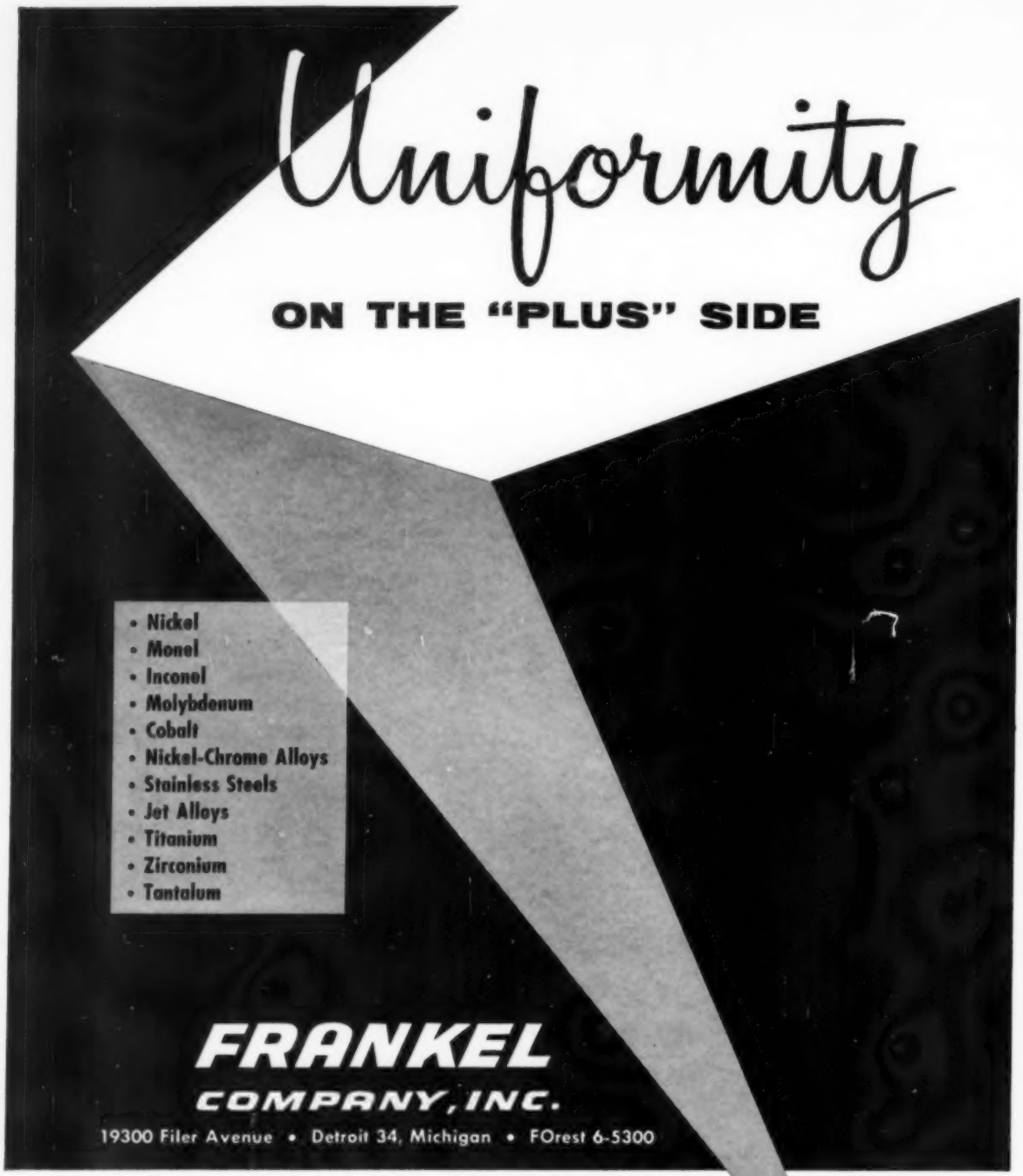
JOURNAL OF

METALS

JULY 1959





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JOURNAL OF

METALS

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July, 1959

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PERSONNEL

► These items are listings of the Engineering Societies Personnel Service, Inc. This Service, which cooperates with the national societies of Civil, Electrical, Mechanical, Mining, Metallurgical, and Petroleum Engineers, is available to all engineers, members and non-members, and is operated on a nonprofit basis. If you are interested in any of these listings, and are not registered, you may apply by letter or resume and mail to the office nearest your place of residence, with the understanding that should you secure a position as a result of these listings you will pay the regular employment fee of 5% of the first year's salary if a non-member, or 4% if a member. Also, that you will agree to sign our placement fee arrangement which will be mailed to you immediately, by our office, after receiving your application. In sending applications be sure to list the key and job number.

When making application for a position include eight cents in stamps for forwarding application to the employer and for returning when possible.

A weekly bulletin of engineering positions open is available at a subscription rate of $3.50 per quarter or $12 per annum for members, $4.50 per quarter or $14 per annum for non-members, payable in advance. Local officers of the Personnel Service are at 8 W. 40th St., *New York 18;* 57 Post St., *San Francisco;* 84 E. Randolph St., *Chicago 1.*

MEN AVAILABLE

Mill Lab Metallurgist; Age 23, Met.E. One month as mineral test engineer in lab promoting sales of equipment for metallurgical equipment manufacturer; 2 years mill engineer, uranium processing mill and mine; 4 months as draftsman on mill design and construction. $550. Any location. S(M)-249

Test Metallurgist; Age 39, Met. E. One year as metallurgical test engineer on copper smelting and refining for mining company; 6 years as smelter metallurgist, foreman on refining copper, lead, and silver with mining company; 6 years as foundry man and teacher for steel foundry. $650. Prefer US or Mexico. S(M)-743

Alloy Producer, Developer; Age 40, Met.E. Three years in charge of laboratory powder metals and surface films; 2 years developing and fabricating beryllium, nickel, manganese, copper, and alloys; 5 months using vacuum techniques; 2 years of research and development of new alloys for gas turbines, heat exchangers, and tube production. $11,000. Prefer West Coast. S(M)-1605

Metal Working; Age 33, MS Met.E., Two years of production, planning, tooling control and design; 3 years processing design machinery for production of mechanical and hydraulic test equipment; 2 years designing tools for manufacturer; 1 year of drafting in research lab. $615. Prefer foreign. S(M)-1508

Metal Control; Age 34, Chemist. Six months evaluating missiles' metals; 2 years preparing aluminum billets for cold extrusion; 5 years precious metal refining and glass fiber production; 1 year of aluminum smelter analysis. Prefer San Francisco area. S(M)-1491

Foundry, Heat Treatment; Age 50, M.S. Met.E. Seventeen years of quality control and processes for melting materials; 3 years automobile tool hardening; 2 years as hardening furnace operator; intermittent teaching of special and general metallurgy. $10,000. Prefer, South or West. S(M)-1283

Production, Sales; Age 39, ME plus Bus. Adm. Three years in developing and producing new metal products for consumer and industrial use, managing and merchandising; 2 years in plastic coatings; 6 years elevator sales, estimates, quotation, survey, engineering and installation. $650 up to start. Prefer San Francisco or West Coast. S(M)-1250

Sheetmetal; Age 34. Eleven years of sales, estimates, buying, preliminary layout, installation, and supervision of sheetmetal work on heat, air conditioning, refrigeration, plumbing, and construction for contractors and shops. $650. Prefer San Francisco Peninsula. S(M)-1215

General Metals; Age 34, Met.E. Nine years as chief of quality, development, production, test procedures, customer contact in the carbide industry; 3 years of machining in carbides; 5 months plating and heat treatment; 2 years as laboratory technician in Naval research. $9000. Prefer West. S(M)-1200

Foundry Engineer; Age 44, Chem. Met. Ten years in production, quality, and cost of steel, cast iron, bronze, and aluminum castings; 10 years as assistant metallurgist in manufacturing, both in US and China. Salary open; looking for opportunity to demonstrate capabilities. Prefer San Francisco. S(M)-1044

Plant Manager; Age 40, M.E. Three years of advanced manufacturing development and processing of machine tools and equipment for metals working, mining, and petroleum industries; 3 years coordinating the manufacture of cars and trucks; 1 year as factory chief on automobile and aircraft parts. Locate anywhere. S(M)-866

Superintendent, Steel Products; Age 48, M.E. Eight years in charge of production, forgings, weldments, pipe, and couplings; 4 years in charge of engineering, manufacturing, and production of components for automobile supplier; 13 years as branch office engineer for large steel producer; 5 years with shipbuilding manufacturer, chief engineer atomic bomb parts, research on magnesium alloys for manufacturer. $13,200. Locate anywhere. S(M)-313

POSITIONS OPEN

Metallurgical Sales Engineer; B.S. in metallurgy or chemical engineering, with a minimum of 3 years experience in steel manufacturing. Will represent company in metallurgical sales accounts and improve relationship with customers for increased markets. Will provide technical data to customers for uses of metallurgical products, and maintain up-to-date knowledge of metallurgical markets, uses of products, and new developments. Travel approximately 60 pct of the time. Salary $8000 to $12,000 to start. Company will negotiate placement fees. Location, Philadelphia area. W7503.

Research Metallurgists; M.S. or Ph.D. Opportunity to do research and grow with young, dynamic organization. Investigations presently underway in the fields of high-temperature metallurgy, electronic materials, ceramics, and others. Location, New York metropolitan area. W7489

Metallurgists; ferro alloys and metals. a) Metallurgy graduate with 5 or more years experience in the non-ferrous field, chiefly in the production and processing of wrought and cast aluminum alloys. Practical knowledge of other metals such as copper and titanium is desirable. b) Metallurgist with good background in steel production, primarily melting and processing unalloyed

(*Continued on page 418*)

IMMEDIATE OPENING

METALLURGIST

Unusually fine opportunity for a qualified Metallurgist at IBM's new facility in the heart of the Bluegrass Country at Lexington, Kentucky—one of America's most modern manufacturing plants.

This is an immediate opening in the quality control department, working with manufacturing on control of production and purchase parts.

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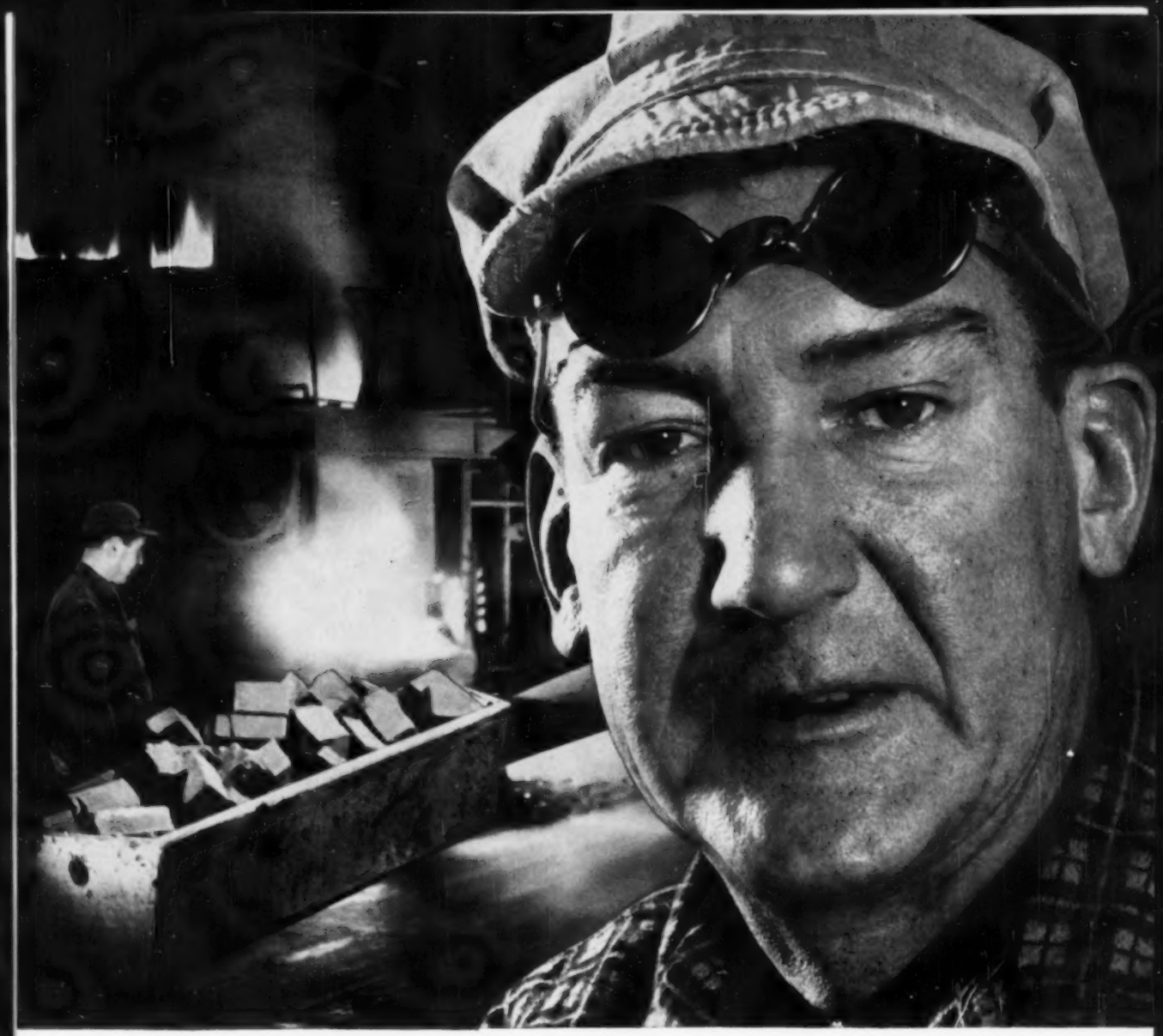

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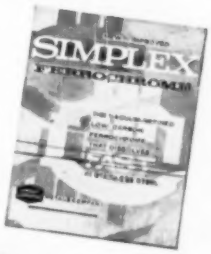

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POSITIONS OPEN

(Continued from page 416)

and low-alloy open hearth and electric furnace tonnage steels. Should have experience in the established practices, including application of ferro alloys, refining agents, quality control, and inspection procedures. Salaries open. Location, Midwest. W7488

Non-ferrous Metallurgists. Responsibilities will include the organization of technical classes and supervision of metallurgical education program, but will not include teaching. Some travel required. This is an administrative opening for a graduate metallurgist. Location, Pa. W7481

Senior Project Engineer for pure metals research. Ph.D. with at least 5 years experience is preferred. Extractive metallurgy and minerals beneficiation background is desirable. Must be qualified to plan, conduct, and supervise research and development projects in modern laboratories. Submit complete résumé and salary requirements. Location, Ohio. W7480

Metallurgical Chemist with 3 to 4 years experience in covering nonferrous and precious metals, including spectrographic analysis and plating. Salary open. Location, New York Metropolitan area. W7455

Metallurgical Engineer for manufacturer of mechanical power transmission equipment; up to 5 years experience desired. For metallurgical quality control and process development work. Good working knowledge of heat treating, physical testing, and metallography required, plus some background in chemical analysis and electro-plating. Location, East. W7453

Engineers. a) Welding development engineer with a B.S. in welding or metallurgical engineering to supervise welding development research projects, investigate fabrication welding problems resulting from new welding procedures, and prepare research reports. One to three years in welding development work or applied welding engineering required, plus thorough knowledge of welding processes and techniques. Experience in metallurgical testing of weldments, fabrication shop practices, welding codes and specifications is desirable. b) Metallurgist or Metallurgical Engineer with a degree in metallurgy and a manufacturing and research background to assist in setting up and supervising development programs and co-ordinating metallurgical and welding data. Three to five years experience desired. Location, upstate N. Y. W7452

Production Manager. Graduate chemist or metallurgist to take complete charge of the production in the rod division (molybdenum, tungsten) in metal refining plant. High Salary. Location. northern N.J. W7450

Foundry Metallurgist. B.S. or equivalent technical knowledge in ferrous foundry operations. Should have served apprenticeship in gray iron foundry, with practical knowledge of molding, core making, and heat treating. Must be capable of establishing controls for electric furnace melting and supervising metallurgical laboratory. Salary commensurate with experience. Location, Md. W7424

Teachers (2), for Department of Metallurgy. Prefer Ph.D. qualified in physical or process metallurgy to act as Department head. Teaching and research. Rank and salaries dependent upon qualifications. Location, West. W7411(c)

Foundry Consultant with at least 10 years supervisory operating experience in ferrous and non-ferrous fields. Salary, $12,000 to $15,000, plus extras. Location, foreign. F7410

Assistant Metallurgist to supervise small laboratory staff. Metallographic examination of all types of metals, ferrous and non-ferrous. Must be able to apply metallurgical principles to raw material control, fabrication of metal products, and other processes. Salary, $8000. W7394(a)

Plant Manager. Graduate metallurgist to take complete charge of small benefication and ore dressing plant employing about 30 people. Salary, $6000 to $7000. Location, eastern Tenn. C7454

Laboratory Manager. Graduate Chem, ChemE. or Met. with supervisory experience or management background. Position with company specializing in quantitative analysis and metallurgical extractive field for mining and smelting companies. Salary open, plus stock in company. Location, Ariz. S-4411

Assayer. Recent actual working experience in practical analytical assays of ores or concentrates (copper, zinc, molybdenum, chrome, and others). Man to isolate foreign or trace quantities and to assay and report prior to, during, and after production. Chemical sales processing company. Salary, $500 to $550. Location, Northern Calif. S-4349

Research Metallurgist. B.S. or M.S. to deal with challenging metallography and metallurgical laboratory practices and studies. Prefer knowledge of powdered metals and interest in electrolytical process development. Will assist in research and new product development of refractory metallurgy. Should have knowledge of physical chemistry and an ability to use advanced laboratory equipment, tests, and instrumentation. Position with manufacturer's laboratory. Salary, $650 to $750 and up. Location, San Francisco Bay area. S-4335-R

Steel Mill Designer with a minimum of 15 years of complete steel mill design. Must have at least 3 years actual work in steel operations, and several years top project engineering-level working with management, client, and design dept. Must now be working on design layout of blast, open hearth, oxygen lance and main equipage, including equipment and building layout. Opening with engineering builder. Salary, $15,000 level. Location, San Francisco. Relocation and placement fee paid by employer. Apply by letter in confidence. S-4277

Metal Coatings Tester. Recent graduate or possess previous laboratory experience. Container manufacturer wants man to make tests on light sheet metal, platings, or organic coatings, including performance, corrosion, and life, and comparisons of new products, processes, and materials. Salary, $450. Location, San Francisco. S-4250

Refractory Researcher with B.S. or M.S. Must be qualified to deal with challenging metallographical and metallurgical laboratory studies relating to new product development of refractories. Knowledge of powdered metals is desired, plus physical chemistry. Must be able to use advanced laboratory equipment, testing, and instrumentation, and possess an interest in electrolytical process development. Salary, $650 to $750 and up. Location, Central Calif. coast. S-4142

Lead Development. Met. or ChE. experienced in or has demonstrated aptitude for development, research, or operational work in connection with lead smelting. Salary, $500 or more. Location, Midwest. S-4181

Sales. Young graduates 1 or 2 years out of school to train with large producing company for sales engineering work relating to the use, application, and sale of base lead to large industrial and manufacturing users. Salary, $600 or so. Location, Midwest. S-4180

Light Metals Development. B.S. or M.S. in Met. or Weld. with 2 years experience in fabrication of ferrous and non-ferrous light metals. Must possess special experience in a) joining problems (welding, brazing,

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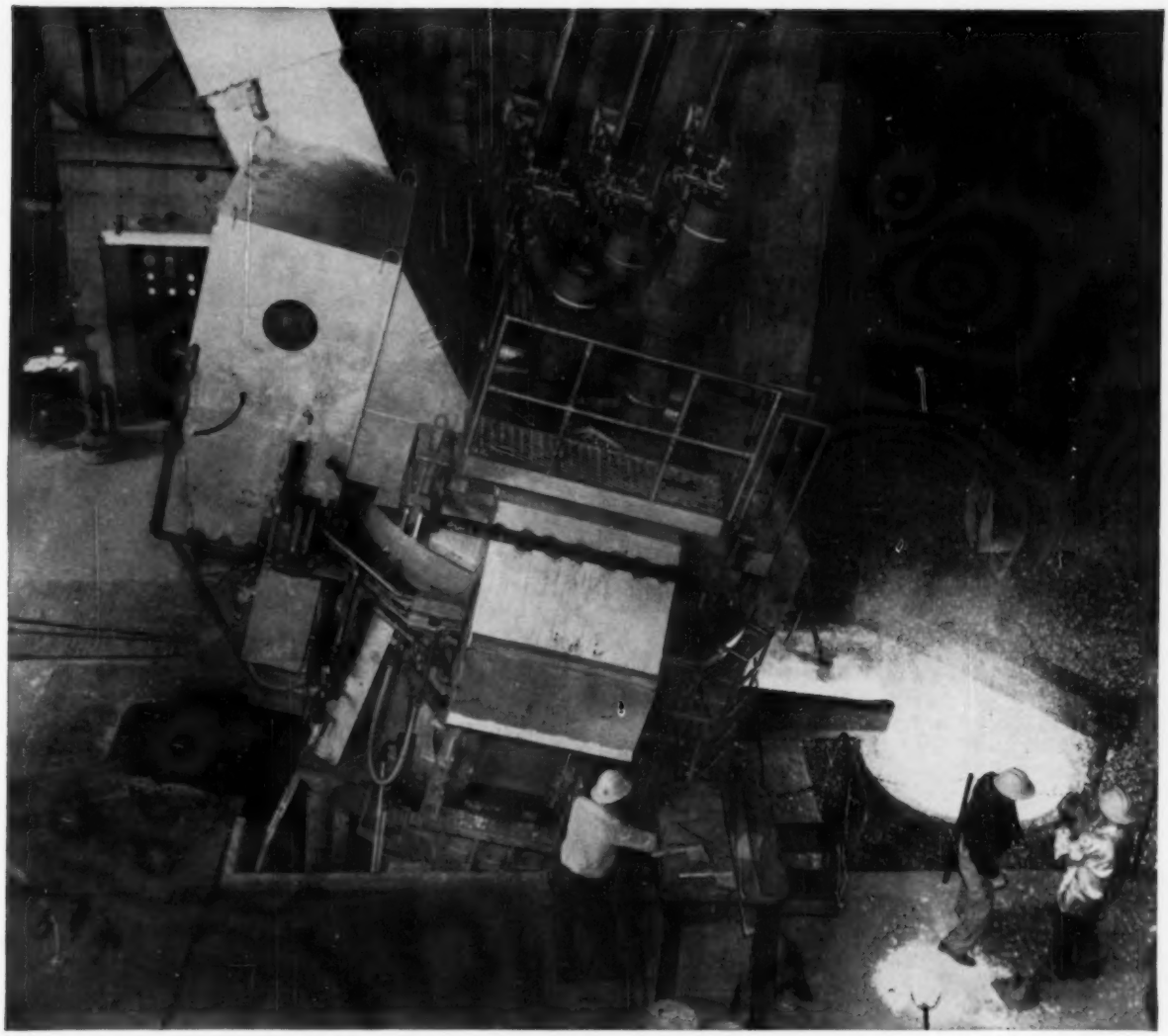

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POSITIONS OPEN

(*Continued from page 418*)

soldering); and b) magnesium castings metallurgy. Will work in a metallurgical and metal finishing group. Salary commensurate with experience. Location, Los Angeles area. S-4160

Production Scheduler. M.E. or I.E. with 1 or 2 years working experience in planning, scheduling, production control, and layout. To assist industrial engineering department in maintaining production schedules and adjust changing order requirements. High speed, high production manufacturing plant. Salary, $500 or so. Location, Santa Clara, Calif. S-4131

Laboratory Metallurgist. Met. E. or ChE. with a couple of years laboratory work in control and testing work, preferably in industrial work—including x-ray diffraction and spectography, though it is not essential. To investigate metal alloys in private laboratory. Salary, $500. Location, San Francisco. S-4081

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Woman's Auxiliary Invites Contributions To Memorial Fund

The Flower Memorial Fund, established in 1954 by the Woman's Auxiliary, AIME, is the outgrowth of members' desire to contribute to the WAAIME Educational Fund in memory of their deceased relatives and friends. The title of the Fund is paradoxical, for donors contribute not flowers, but a memorial in the form of money to be used to educate students in mining, metallurgy, and petroleum.

Contributions to the Fund are acknowledged through inscription of the donor's name and that of the deceased in The Flower Memorial Book. A card is also sent to the donor and to the family of the bereaved. Amount of each donation is known only to the asst. treasurer of the Educational Fund. The national treasurer receives all funds at the end of each year.

With the addition of $2599 during 1958, the resources of the Flower Fund stand at $4200. As the Fund continues to grow through the donations of members, more students will be encouraged to continue their studies by calling upon the Educational Fund Committee for financial assistance.

In arranging for a memorial, the donor should remember to give not only his name and address, but also the name and address of the person in the bereaved family to whom the card, advising of the memorial, is to be sent. Checks should be made payable to the WAAIME Educational Fund, Flower Memorial, and sent to *Mrs. Edward H. Thaete, Schuyler House, Fort Hill Village, Scarsdale, N. Y.*

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TWO TEACHERS, Department of Metallurgy. One, department head, Ph.D. preferred, physical or process metallurgy. Teaching and research. Rank and salary dependent on qualifications. Apply President, Montana School of Mines, Butte, Montana.

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Responsible supervisory position vacancies in Research and Development involving Powder Metallurgy, Process Metallurgy, and Physical Metallurgy. Supervision will encompass investigations in the areas of alloying, joining, slip casting, rolling, forging, extrusion, forming, corrosion studies and testing programs including x-ray diffraction, creep, stress rupture, and fatigue.

If you meet the following requirements:

Have five to ten years experience in Research and/or Development possess a minimum of a B.S. in metallurgy or preferably an M.S., are interested in an organization with a bright future.

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MILTON STERN

Electrochemical Prize Bestowed on Stern

Dr. Milton Stern, member of the Niagara Frontier section of AIME, has won the Electrochemical Society's Prize to Young Authors for 1958. It marks the second time that Dr. Stern has won this award, the first coming in 1955. His most recent recognition was for his paper entitled *The Mechanism of Passivating-Type Inhibitors*, published in the *Journal of Electrochemical Society*.

Dr. Stern, who is Technical Supervisor of Metals Research at Union Carbide Metals Company's Research Laboratories, Niagara Falls, N. Y., received the award May 5 at the Sheraton Hotel, Philadelphia. He is responsible for the research program in corrosion, ceramics, reactive metals, and iron and steel at Union Carbide's Research Laboratories.

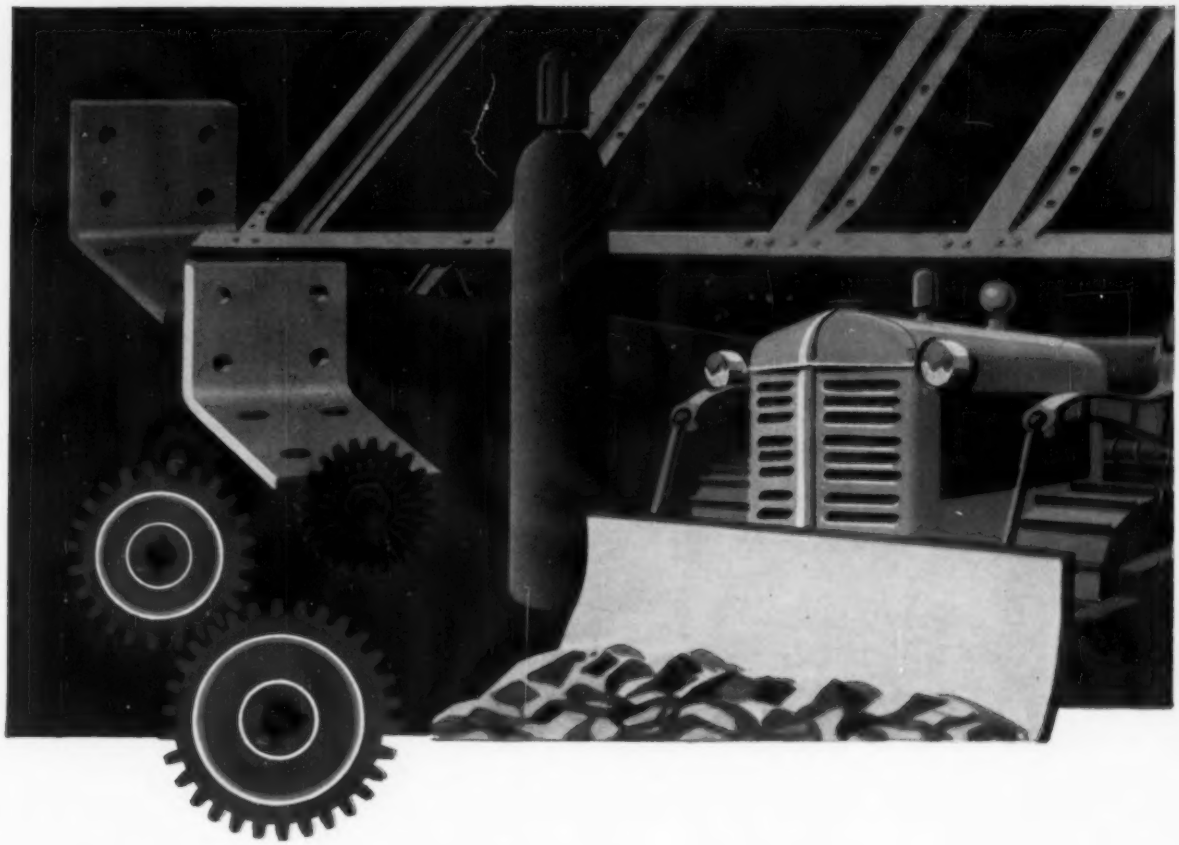
Dr. Stern, chairman of the Niagara Frontier section of the National Association of Corrosion Engineers, is responsible for the recent discovery of a more corrosion resistant titanium which is formed by the addition of small quantities of a noble metal, such as palladium or platinum, see p. 308 of the May issue of JOURNAL OF METALS.

Set Foundry Congress

The 26th International Foundry Congress will meet in Madrid, Spain, Oct. 4-10, 1959.

The conference will be held in conjunction with the IV General Meeting of The Instituto Del Hierro Y Del Acero, under the auspices of The International Committee of Foundry Technical Associations.

Two days of technical sessions are scheduled for the meeting, during which papers will be presented and discussed. The four-day session will also feature sight-seeing excursions, banquets, entertainment, and special programs for ladies present.



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Many engineers are taking advantage of the special properties which columbium imparts to steel, at a production cost which is most favorable. Properties obtained in the as-rolled condition afford such advantages as finer internal grain structure, higher yield strength, excellent weldability and increased toughness.

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These vessels, called "Dual-Paraboloid" fermentation tanks, are shaped like giant toasters. They're 21 feet long, 13 feet high, and 12½ feet at the widest point. Solar Chicago, Division of U.S. Industries, Inc., makes them from 13-gage Type 304 Stainless Steel sheets that are curved and welded together to form a cornerless interior. 1″ x 4″ ribs are welded around the outside of the tank and all welds are ground to a uniform finish.

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These tanks weigh 5 tons and they will replace old, square-cornered ones that weighed about *20* tons. Breweries are happy . . . the cornerless, Stainless tanks are easier to keep clean, and because they're off the floor, the plant itself stays cleaner. And because they're Stainless Steel, they will probably never have to be replaced.

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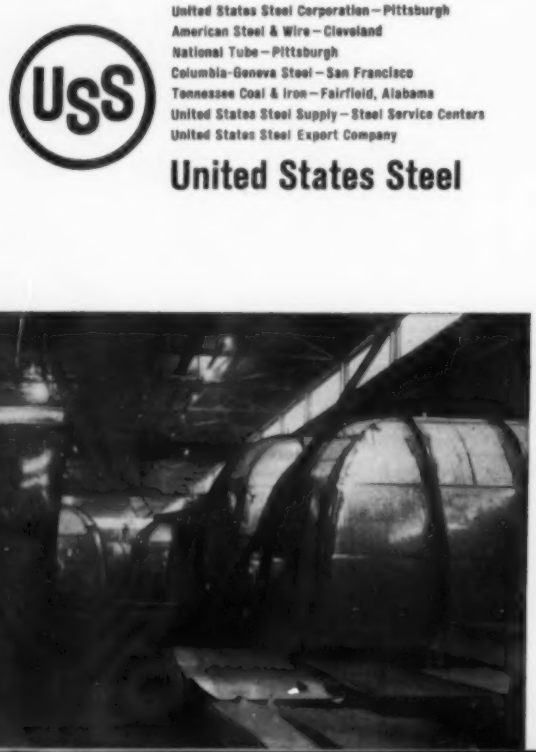
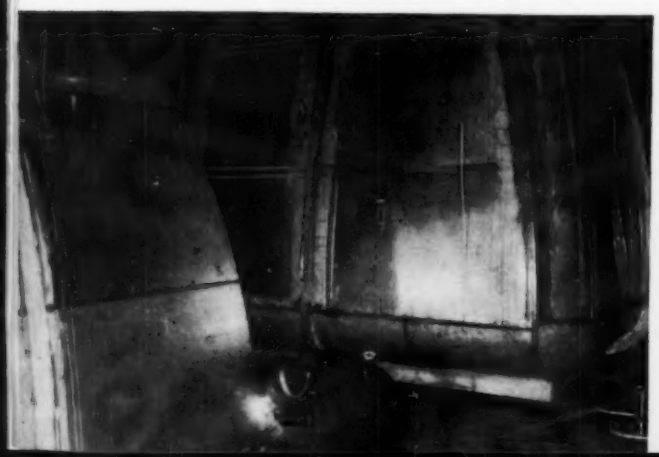
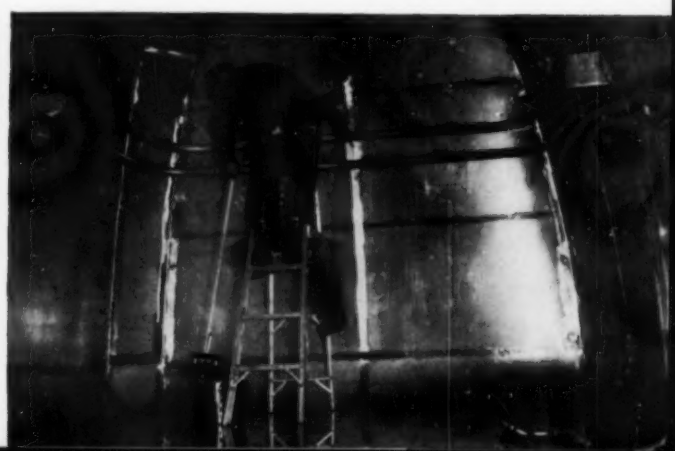


USS

United States Steel Corporation—Pittsburgh
American Steel & Wire—Cleveland
National Tube—Pittsburgh
Columbia-Geneva Steel—San Francisco
Tennessee Coal & Iron—Fairfield, Alabama
United States Steel Supply—Steel Service Centers
United States Steel Export Company

United States Steel





Seek Titanium Papers For February, 1960 Meeting of AIME

Papers on new titanium and titanium alloy research are requested for the February, 1960 Annual Meeting of the AIME.

David W. Levinson, Chairman of the Titanium Committee's technical program, urges that interested persons contact him. Address inquiries to: *David W. Levinson, Asst. Mgr. of Metals Research, Metals Research Dept., Armour Research Foundation of Illinois Institute of Technology, 3350 South Federal St., Chicago 16, Ill.*

A half-day session devoted entirely to titanium research is planned for the meeting. Authors will present their papers at that time.

Physics Translated from the Russian

Soviet Physics—Solid State is the English language translation of the USSR Academy of Sciences journal, *Fizika Tverdogo Tela*, now available in this country.

Offering results of theoretical and experimental investigations in the physics of semiconductors and dielectrics, as well as applied physics associated with these problems, this periodical publishes papers on electronic processes taking place in the interior and on the surface of solids.

Subscription for the monthly magazine is $55 a year for individuals; $25 for libraries. For more information and to place orders, address: *Mrs. Litow, Circulation Dept. American Institute of Physics, 335 E. 45th St., New York.*

Proceedings of High Temperature Materials Meeting Now Available

Proceedings of the AIME Conference on **High Temperature Materials,** held in Cleveland in 1957, has now been published by *John Wiley & Sons, Inc., 440 Fourth Ave., NYC.* Topics of the book include: Cobalt and nickel base alloys; cerments and intermetallics; refractory metals; strengthening by dispersion of insoluble particles; vacuum melting and its effects on properties; effect of testing environment on properties; and oxidation resistance.

Complete price of the 544-page book is $17.50, but members can get it for $14—a 20 pct discount off list price—by ordering through *The Metallurgical Society of AIME, 29 W 39th St., New York 18, N. Y.*

PERSONALS

Institute members recently elected to fill vacancies on the council of The Institute of Metals, London, are: **G. L. Bailey,** director, The British Non-Ferrous Metals Research Association, president; and **W. O. Alexander,** asst. research manager, Imperial Chemical Industries Ltd., metal div., Birmingham.

Robert G. Matters, formerly asst. director of research, in charge of materials service section, Allis-Chalmers, has been named to head that company's new materials engineering section, steam turbine department.

Charles E. Hanson, Plastic Metals, div. of National-U.S. Radiator Corp., has been elected president of The Metal Powder Producers Association for the 1959-1960 term. Elected directors of the Association were: **Robert R. Hendren,** Hoeganaes Sponge Iron Corp.; and **Don O. Noel,** Metals Disintegrating Co. Inc.

Dr. Bernhard Blumenthal, associate metallurgist, Argonne National Laboratory, has been granted a leave of absence to assist Belgium's Centre d'Etude de l'Energie Nucleaire (CEN) in plutonium research and development.

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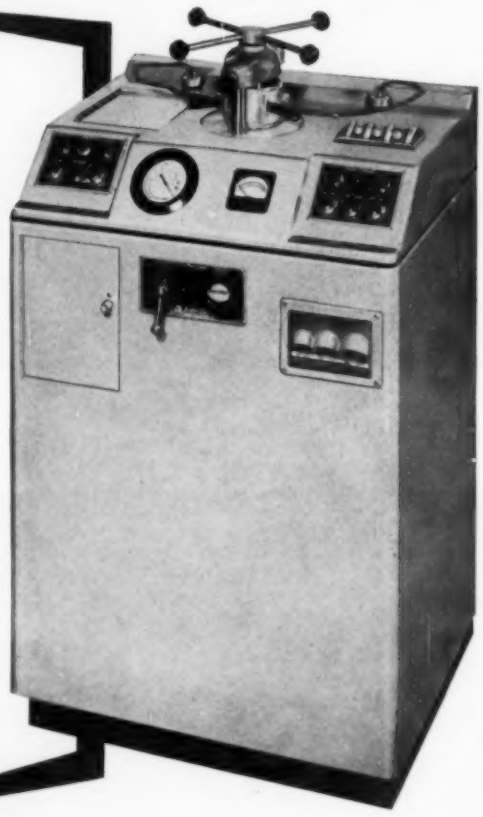

Metallurgical Society Joins Engineering Management Conf.

The Metallurgical Society of AIME will be one of the sponsoring societies for the Seventh Engineering Management Conference to be held in Los Angeles, Sept. 18-19. The Metallurgical Society will participate for the first time with the American Society of Mechanical Engineers and the American Institute of Electrical Engineers, the prior sponsors.

Recognizing the need of members who are constantly climbing up the rungs of industry from engineering to managerial positions, the Society hopes that these management conferences will help equip members for such assignments. Tentative plans for the Conference call for a four-part program encompassing a variety of subject headings. Under the heading, Development of Engineering Managers, talks on the *Philosophy of Engineering Managers* and *Developing Managerial Abilities* are scheduled.

Case histories of Engineering Managers' Development is next on the agenda, with a recounting of engineering managers' development on both large-company and small-company levels. *Development of Engineering Managers in a Governmental Organization* is also to be discussed.

New Concepts of Engineering Controls is the third area to be covered. Subject titles include *Control of the Engineering Function* and *Development of Integrated Engineering Controls.* The fourth and final portion of the program will take up Engineering Planning. *Decision Making in Engineering* and *Engineering Programs for New Frontiers* will comprise this section of the managerial conference.

Meanwhile, The Metallurgical Society has appointed an *ad hoc* Committee on Engineering Management to consider future activities in this field. J. C. Kinnear, Jr., is the Committee chairman. H. K. Work and Bruce Old of the Committee were instrumental in developing plans for participation by The Metallurgical Society this year.

Mechanical Working Committee Plans Flat Roll Confab

A second conference on Flat Rolled Products will be held in Chicago's Del Prado Hotel on Jan. 20, 1960, under the auspices of the Mechanical Working Committee of the Iron and Steel Division. Papers are planned on such subjects as *Machine Scarfing . . . Selection of Ingot and Slab Sizes for the Modern Strip Mill . . . Scaling Problems in Hot Strip Rolling . . . Residual Stresses in Cold Rolled and Temper Rolled Strip . . . Results of Examination of Roll Texture and Strip Texture in Cold Rolled Strip . . .* and *Processing and Properties of Magnetic Materials.*

The first conference under the Mechanical Working Committee's sponsorship, on Flat Rolled Products, was held last January. The Committee's chairman is Ralph Hindson. C. F. Schrader is vice-chairman; E. L. Robinson, past-chairman, P. B. Smith, secretary-treasurer; and T. E. Dancy, E. W. Earhart, Albert Lami, E. W. Mahaney, Michael Tenenbaum, and P. H. White are members of the executive board.

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(Agency)

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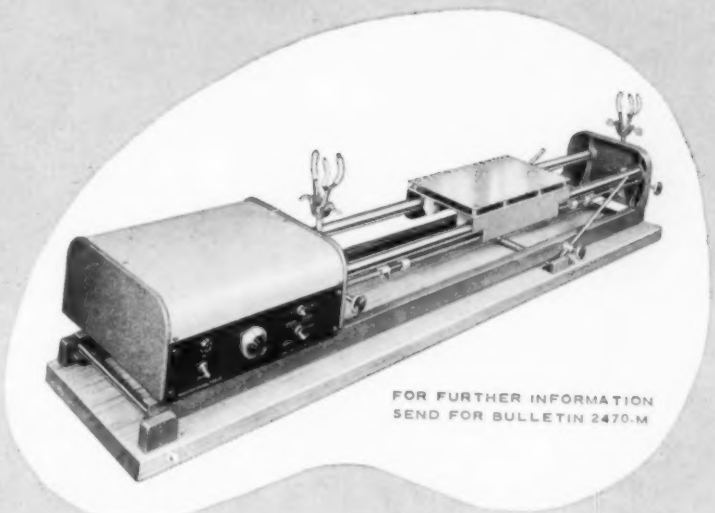

Completely automatic equipment for purification of solid materials by the zone melting technique.

The **Model 2470** apparatus holds a glass or quartz tube inside of which is placed the charge of material to be purified. A moving table holds either induction heating coils or electric resistance heating rings which surround the tube. A synchronous motor and variable speed reducer drive the table at a constant rate variable from 0.36 to 9 inches per hour. Adjustable stops limit the table travel and actuate a rapid return mechanism. Multiple-pass zone melting is thus completely automatic.

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In nuclear reactors as studs, or in steel mills as heavy-duty gears, or in rotary shears as shafts 4340 Nickel alloy steel proves again and again that it gives the best combination of strength, toughness, ductility, and resistance to fatigue. Performance proves that 4340 gives the properties which are best suited for moderate-to-heavy section parts.

Performance on these jobs also proves that AISI 4340 responds reliably to all forms of heat treatment. In the stud shown above, for example, 4340's ability to be hardened easily throughout large sections was of tremendous value. And its ability to be machined *after* heat treatment was valuable in thread cutting.

The high hardenability of this Nickel alloy steel, its machinability as heat treated up to 340 BHN, can prove valuable to you, too.

Why not look into the possibilities of 4340 Nickel alloy steel? Most Steel Service Centers throughout the country carry this steel in stock—will make deliveries on a "next door" basis. Write Inco for a list of Steel Service Centers stocking 4340 Nickel alloy steel. A postcard will do it.

*Shippingport Nuclear Power Station. Operated by Duquesne Light Company. Designed by Westinghouse Electric Corporation. Reactor Vessel designed and manufactured by Combustion Engineering, Inc.

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INCO NICKEL

NICKEL MAKES ALLOYS PERFORM BETTER LONGER

Nickel producer 'on schedule'

The Manitoba project, destined to be the world's second largest source of nickel, is proceeding on schedule, according to John F. Thompson, Chairman of the Board of The International Nickel Co. of Canada, Ltd. Underground development and construction of surface and town facilities at Thompson, Manitoba are now underway. Exploration of ore bodies has revealed that the mine would be able to produce 75 million lb of nickel annually.

Announcement was also made that Inco will construct an electrolytic nickel refinery at the Thompson site capable of taking care of the mine's entire output. The refining process to be used was developed by the Company, and has been demonstrated in commercial operation in a section of its refinery at Port Colborne, Ont., Canada, since 1956 (See JOURNAL OF METALS, June, 1958, pp. 414-418). A main feature of the process is the direct electrolysis of nickel matte, which eliminates high-temperature oxidation and reduction operations. Nickel sulfide of low-copper content from bessemer converters will be cast directly into sulfide anodes and electrolyzed for the production of high-quality nickel.

When combined with Inco's production in the Sudbury District of Ontario, the Manitoba project will increase the Company's total annual nickel production capacity to 385 million lb.

J & L plans two LD furnaces

Construction of two of the world's largest LD furnaces, and one of the largest blast furnaces in the US will be started at the Cleveland works of Jones & Laughlin Steel Corp. this summer.

Approximately $50 million will go into the program, which "will equip the Cleveland plant as one of the most modern in the country," according to J. R. Powell, manager of the Cleveland works.

The new LD furnaces are expected to produce 160-ton heats, at a total annual rated capacity of 1,200,000 tons for both furnaces. Compare this to the Company's Aliquippa, Pa., furnaces, presently the largest of their type in the world, which are making 83-ton heats.

The new blast furnace, meanwhile, will have the largest hearth diameter and working volume in the US. The 110-ft furnace will have a 32-ft hearth diam and a working volume of 65,000 cu ft. Its daily rated capacity of 2500 tons will increase the yearly rated iron capacity at the Cleveland works from 866,000 to 1,800,000 tons.

Three 220-ton stationary open hearth furnaces will continue to operate, as will two large new electric arc furnaces. The three open hearth furnaces have already been equipped with oxygen lances and basic roofs to increase both steel quality and production rate.

All of the latest developments for abatement of air pollution will be employed with the new facilities, Works manager Powell explained. These include electrostatic precipitators for the LD, open hearth, and electric furnaces, and an orifice scrubber for the new blast furnace.

Make zirconium-copper alloy

A zirconium-copper alloy possessing both good electrical conductivity and high-temperature strength properties has been developed by American Metal Climax, Inc. The new material—known as AMZIRC alloy—is made of high-conductivity, oxygen-free copper and controlled concentrations of high-purity zirconium.

The alloy is also distinguished by its high strength level developed in cold working, and the fact that it retains its strength at elevated temperatures. A typical bar of AMZIRC cold-rolled 60 pct and aged for 1 hr at 400°C, exhibits the following qualities: tensile strength, 63,000 psi; yield strength, 59,000 psi; and elongation, 12 pct. At 400°C, the short-time tensile strength is 46,500 psi.

Foote expands plant

Expiration of Foote Mineral Company's lithium contract with the Atomic Energy Commission on April 30, 1959, may affect short-term profits, but the long-range outlook is good, President L. G. Bliss reported.

Bliss also revealed plans to expand the Company's electrolytic manganese production facilities at Knoxville, Tenn. Completion of building, making it the second expansion in three years, is scheduled for 1960.

The growing use of stainless steel and the acceptance of electrolytic manganese's use in mild steel were cited as chief reasons for the expansion.

Use hot-blast cupolas with L-D

Acme Steel Co. plans to introduce the use of hot-blast cupolas to American LD steelmaking.

With the exception of a cupola-LD combination in Witten, Germany, all LD operations in the world now use blast-furnace hot metal. The German plant was described in the September, 1958 issue of JOURNAL OF METALS, pp. 599-604.

Acme's announcement came with the news that it has been licensed by Kaiser Engineers' for LD steel operations in its Riverside, Ill., plant. The Midwestern specialty steelmakers' plant will house two hot-blast cupolas and two 50-ton LD furnaces, capable of producing up to 600,000 ingot tons of steel annually.

REPORTER

Biggest LD capacity planned

An order for a sixth LD furnace is expected to give McLouth Steel Corp. the largest LD steel capacity in the US. The order, placed with Pennsylvania Engineering Corp., will bring another Pecor-built furnace to McLouth's Trenton, Mich. plant. The new LD furnace, scheduled for operation late this year, will have a nominal capacity of 110-tons per heat. McLouth's installations already include two 80-ton and three 35-ton LD furnaces.

Invent molybdenum process

The invention of a new process for the production of molybdenum metal powder by a rapid, single-stage reduction of molybdenum oxide at high temperatures has been announced by Metals & Residues Inc., Springfield, N. J. B.H. Davidson, technical director, estimated that the single-stage reduction process increases the rate of molybdenum powder production by a factor of 5 to 8 times over the rates obtainable by current practices.

Atomic fuel element studied

Union Carbide Metals Co., Div. of Union Carbide Corp., has signed a $128,000 contract with the Atomic Energy Commission to study a new atomic fuel element, as part of a study to find fuels for high-temperature reactors. In order to provide efficient and inexpensive reactors, scientists contend that improved nuclear fuels and higher temperature operation must be developed. A uranium carbide fuel clad with columbium will be under observation by the Union Carbide Metals Co. It is hoped that this material will operate satisfactorily at 1500° to 2000°F.

Purify titanium

A new process that removes oxygen and nitrogen contaminants in vacuum-melted titanium ingots to below 0.1 pct is announced by Johnston & Funk Metallurgical Corp., subsidiary of Mallory-Sharon Metals Corp.

The removal is well below the level at which embrittlement can take place, they explain. It is thought that the process will have application in other vacuum melting techniques, titanium scrap recovery, and titanium welding.

The method involves the arc melting of titanium and titanium alloys with an electrode containing titanium and a second metal which deoxidizes and denitrides the titanium being processed. In operation, a consumable electrode of titanium and a small percentage of the contaminant-removing metal is placed in the furnace well. As the electrode heats, the second metal boils off at approximately 1500°C, somewhat below the boiling point of titanium. The resulting gas expands around the arc, combining with the oxygen and nitrogen in the titanium. The resulting oxides are insoluble in titanium, stable at high temperatures, and highly volatile, so they can be drawn off by a vacuum.

Phoenix plans oxygen steel plant

A $40 million LD steelmaking plant is being planned by the Phoenix Steel Corp., formerly Barium Steel Corp. The new plant is to be erected at Burlington, N. J.

Cuban nickel project readied

Freeport Sulphur Co.'s facilities for extracting nickel and cobalt from Cuban ores are scheduled for completion this year. The recent Cuban revolution did not seriously affect work progress, it is reported. The project includes mining and ore concentrating facilities at Moa Bay on the Northeastern coast of Cuba. Refinery operations will be in the US, at Port Nickel, near New Orleans, La.

Scandium under study

Study and production of the rare metal scandium has been authorized by the Air Force in two contracts let to Union Carbide Metals Co., div. of Union Carbide Corp. The contracts, totalling nearly $60,000, were awarded by the Materials Laboratory, Air Research and Development Command, and the Air Material Command of the US Air Force at Wright Air Development Center.

One of the contracts provides for a detailed study of the metal's physical, mechanical, and chemical properties. Of particular interest to the Air Force is the fact that scandium has a density comparable to aluminum, while having a relatively high melting point of 1550°C—2½ times that of aluminum.

The second contract calls for production of 1 lb of scandium to be used in properties testing. The 99 pct pure sample will cost $20,000 to produce, it is estimated. Since its discovery in 1879, scandium metal has never been sold in commercial quantities, and known mineral deposits containing the metal are quite rare.

VOEST expands LD production

A new LD furnace with a 0.6 million metric ton annual capacity will bring the United Austrian Iron and Steel Work's (VOEST) total crude steel capacity to 1.7 million metric tons on July 1st.

Meanwhile, the LD process has been developed to the extent that ore with a phosphorus content exceeding 1 pct can be used. The Salzgitter steel works in Germany reportedly intends to use this technique when it expands its plant.

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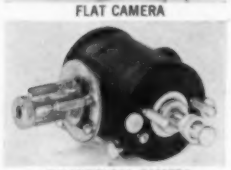

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Cameras used with the Crystalloflex II can be operated simultaneously at four x-ray ports, each of which is equipped with an individually timed shutter. Rating of this compact table model is 25 to 60 KV in 5 KV steps. Tube current control is continuous from 0 to 40ma. Overall size of the unit is 24" wide x 32" high x 22" deep. The Crystalloflex II can also be tilted so that the tube may be operated horizontally. All these features make this generator an excellent tool for chemists, metallurgists, physicists and biologists whose research projects usually entail a high volume and wide variety of film work.

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AUGUSTUS B. KINZEL RECEIVES STEVENS POWDER METALLURGY AWARD

An oasis of grass and trees, dormitories, and classroom buildings overlooking the Hudson River, and beyond the towering skyscrapers and teaming tenements of Manhattan . . . might describe Stevens Institute of Technology, situated high on a river bluff in Hoboken, N. J.

There, on May 6th a joint meeting of the New York Powder Metallurgy groups of the AIME was held in the school's new Science-Engineering Building. Tours of the new building were one of the highlights of the afternoon. Seen was an electron microscope, the latest X-ray diffraction equipment and spectrographs, as well as conventional metallurgical and metallorgraphic equipment.

Also toured was the Powder Metallurgy Laboratory—the first of its kind on any college campus in the US. Established in 1938, the Laboratory has since conducted basic research in the properties of metal powders of many descriptions, and has carried on pioneering work in their handling and treatment. More recently, work has been concentrated in the Laboratory's new method of slip casting metal powders—an important new development.

Dr. Augustus B. Kinzel (center) received the Stevens Powder Metallurgy Medal from Dr. Willis H. Taylor, Jr., chairman of the Stevens Institute of Technology's Board of Trustees, in the Institute's new Science Engineering Building, May 6th. Stevens President Jess H. Davis looks on.

Panel discussion

At 4:15 p.m. members of the two AIME groups gathered in the Engineering-Science Building for a panel discussion on the Slip Casting of Powder Metal Pre-forms.

Following are brief summaries on each of the talks:

Clay Slip Casting in the Ceramic Industry (G. W. Phelps, United Clay Mines Corp.)—A clay casting slip is defined as being a formulation whose special properties are dependent upon the presence of a deflocculated clay-water system. The function of various clays in providing these qualities was next discussed in the light of present theory. Following, the mechanism of casting and the relationship between casting and deflocculation was illustrated.

Slip Casting Fine Particulate Metal Powers (D. St. Pierre, General Electric Co.)—Discussion centered on the applications of the slip casting process to metals, with particular emphasis on the modifications of technique that are necessary when

(Continued on next page)

The Anson Wood Burchard Memorial Building was dedicated May 23rd on the Stevens Institute of Technology campus. The seven-story science-engineering structure houses the departments of metallurgy, electrical engineering, and physics. See story (right).

Engineering Building Dedicated at Stevens

Dedication of the Anson Wood Burchard Memorial Building—one of the largest engineering education buildings in the country—was held on the Stevens Institute of Technology's campus May 23rd. The seven-story building is named for Anson Wood Burchard, an 1885 Stevens graduate, whose estate helped finance the $2 million structure.

The departments of metallurgy, physics, and electrical engineering are housed within the building's 100,000 sq ft of floor space. Although first dedicated on this year's Alumni Day, the shortage of laboratory and classroom space on the campus forced occupany in 1958 while the interior was still incomplete.

President Jess H. Davis and Dr. Willis H. Taylor, Jr., chairman of the Stevens Board of Trustees unveiled the commemorative plaque which formally dedicated the building.

(Continued from previous page)
one goes from ceramics to metals.

Slip Casting as a New Powder Metallurgy Technique (H. H. Hausner, Consultant)—The application of slip casting to metal powders not only confronts the metallurgist with an entirely new set of processing variables for forming shapes, but with new aspects of sintering and the control of shrinkage during sintering as well. Powders are not exposed to any sizeable pressures in the process, and since they are not deformed, contain minimum stresses. Sintering of slip castings is actually a special case of sintering loose powder particles for which there is little data available. The difference between sintering slip cast metal powders and pressure-compacted metal powders can best be expressed in terms of grain boundary diffusion and grain boundary movement.

Slip Casting of Commonly Employed Metal Powders (E. B. Wilson, Stevens Institute of Technology)—Effects of particle shape and size distribution on slip characteristics and the sintered properties of castings were shown. It has been found that solidification of such castings occurs in several stages. This solidification, together with the mechanical properties of sintered castings, was discussed.

Industrial Application of Slip Casting to High Metal Cerments (L. M. Schifferli, Jr., Haynes Stellite Co., Div. of Union Carbide Corp.)—A flow diagram showing the reduction to practice of the slip casting process as applied to metal-ceramic compositions was given. Steps include slip making, raw materials and slip properties, drain and cored casting operations, and sintering. Capabilities and costs of the process were discussed briefly.

Evening program

Events next moved up the tree-shaded paths to the Castle Stevens, ancestral home of the Stevens family, which commands a striking view of midtown New York. While enjoying pre-dinner refreshments, members watched the HMS Queen Mary make her way down river and out to sea. A roast beef dinner served in a manner befitting the grandeur of the old mansion followed.

Highlight of the evening program was the presentation of the Stevens Institute of Technology's Powder Metallurgy Medal to Dr. Augustus B. Kinzel, Vice President-Research, Union Carbide Corp., and Past-President of the AIME.

The award, established in 1941, was presented by Dr. Willis H. Taylor, Jr., Chairman, Stevens Board of Trustees, for Dr. Kinzel's "outstanding achievement in the field of powder metals."

Associated with Union Carbide since 1926, Dr. Kinzel has been engaged in research in the areas of metallurgy, applied mechanics, industrial gases, and nucleonics, in addition to powder metallurgy.

Following acceptance of the award in the Stevens Campus' Science Engineering Building, Dr. Kinzel delivered the Medal lecture entitled *Powder Metallurgy and the Microcosm.*

Pointing out that lecturers in an academic environment are always expected to define the terms that they use, Dr. Kinzel commenced by defining his particular microcosm—the world in which the unit of measure is the micron. This is an intermediate-sized world, smaller than the microscopic, larger than the atomic, wherein much of the future of powder metallurgy lies.

Dr. Kinzel explained reasons for the development of powder metallurgy techniques: 1) Lower cost for producing hard-to-form shapes; 2) Production of shapes from hard-to-melt metals—although this is not a major reason today, because of new melting techniques; 3) Achievement of planned heterogeneity to get special properties, such as self-lubricating bearings, and finally 4) Attainment of properties that cannot be produced by following the melting and freezing laws of physical chemistry.

The latter point is particularly important to the future of powder metallurgy; by the proper techniques, it is possible to design and then put together completely new microstructures, with enhanced properties. Dr. Kinzel emphasized that as we go along, we will see more mechanical production of materials formed according to predetermined microstructures. This will require the use of materials on the order of one micron in size.

In this same microcosm are metal whiskers. The strength of whiskers is particularly interesting—in fact, quite astounding. Per unit area, their strength is many times greater than a cross-section of the very same metal. Also, the temperature at which brittleness occurs is much less with whiskers; therefore ductility extends to much lower temperatures than in larger sections. Furthermore, whiskers exhibit greater strength at elevated temperatures due to their minute grain size. Dr. Kinzel pointed out that powder metallurgy may be able to put micron-size particles together to approach such properties in sections large enough for engineering application. A steel with #17 grain size, average diameter one micron, would be a case in point with 250,000 psi ferrite!

Here is a whole new working approach leading to a new world for powder metallurgy to conquer, and as Dr. Kinzel pointed out, the surface hasn't been scratched yet. This is the world of the microcosm of micron size.

RESEARCH METALLURGISTS

The J&L Research Division wishes to add to its staff in 1959 several professional metallurgists, to broaden the scope of the Corporation's research programs in carbon and stainless steels.

Of specific interest are physical metallurgists (Ph.D., or M.S. with related research experience) to conduct projects in high-temperature materials, alloy development, corrosion, general applied physical and mechanical metallurgy.

Several openings exist also for recent B.S. graduates, in the fields described above and in projects dealing with steelmaking process analysis and development. For the B.S. graduate interested in a permanent research career, Pittsburgh offers unmatched opportunity for continued education at the graduate level.

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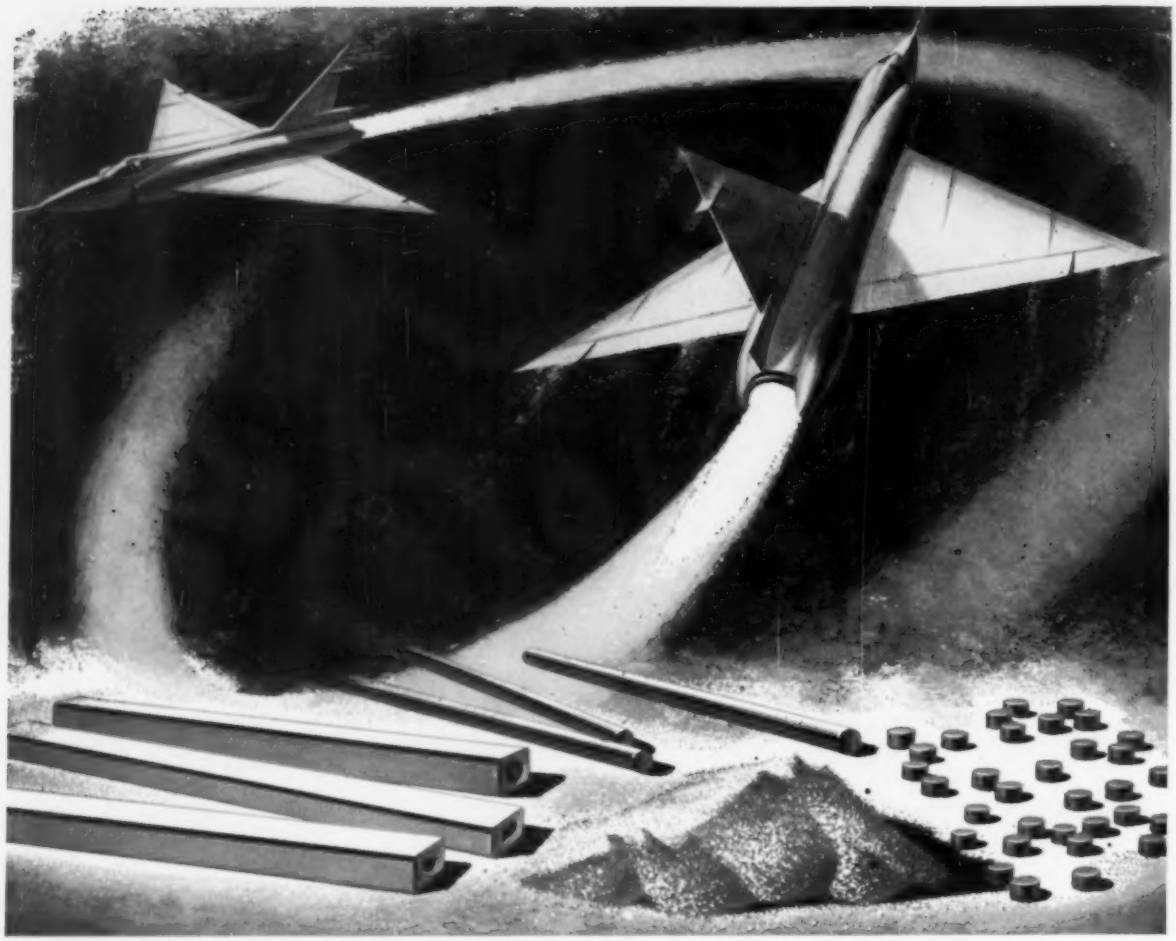

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EDITORIAL

Publication and Professional Advancement: An Evaluation

Item: Western Reserve University's Center for Documentation and Communication Research plans to install a machine that will search 100,000 abstracts per hour.

Item: An ACS member complains: "Now that our meetings have become too large, should we not put more emphasis on quality? Would not a program of fewer—but better—papers be preferable to our present bloated monstrosities?"

Item: Dr. P. R. Hawley, Director of the American College of Surgeons was recently quoted as follows: "I think it would be a reasonable assumption that 90 pct of the medical literature of today could be dispensed with; and that this would increase, rather than diminish, the dissemination of medical knowledge."

It is well known that the academic scholar in any field must publish to advance professionally. This also holds true for the industry-employed research worker. It is equally well known that the volume of scientific literature published annually is becoming so large that it is almost impossible for a competent worker to keep abreast of developments in his own specialty, much less his entire field.

The items above reflect differing views as to how this problem should be coped with. Needless to say, every worker is not going to have a machine to do his literature searching for him, and even if he did, the machine could not distinguish valuable information from rehashes that are too seldom labeled as *reviews*.

Criticism of the *necessity to publish* is not limited to those who live apart from the academic world. William Sloane, Director of the Rutgers University Press, recently said, "The result [of the necessity to publish] is another book, and another. Often these are not books aimed at the reader, but at a special aspect of the professor's own subject. . . What might have been a useful monograph becomes a book padded and extended by bolstering evidence. . ."

Dr. Hawley has little to say for this tendency in the medical profession: "That professional reputation is so influenced by the production of so-called scientific papers induces too many medical men to rush into print with a sorry dish of warmed-over tripe. . ."

When it comes to professional advancement, it would seem that there is more truth than poetry to the lines,

"I multiply your projects by the words I can't pronounce,
And weigh your published papers to the nearest half an ounce."

If it is accepted that the overwhelming volume of literature in any given field is at least partially caused by this *necessity to publish*, it is easy to see that the problem can be attacked from either end. The necessity must be taken away (would it be too rash to suggest ability as a teacher as a criterion for advancement?) or material getting into print must be selected with greater care.

The problem is a general one, and our profession is certainly not immune. As both a publisher and professional society, The Metallurgical Society should certainly find this a worthy subject of study.

J. J. Burke

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GRANTS AND FELLOWSHIPS

► **United States Steel Foundation Inc.** has announced a $2,350,000 program of Aid-to-Education, with grants to 541 privately supported liberal arts colleges, 125 universities of national or regional importance, 22 science and engineering institutes, and 25 organizations devoted to elevating the quality of higher learning in America and to opening new frontiers of basic knowledge.

The Foundation's eight-part program includes: operating grants, $667,000; major purpose or capital grants, $1 million; teaching aid, $180,000; fellowships, $190,000; project aid, $113,000; quality improvement, $35,000; association support, $80,000; and basic research grants, $60,000.

No additional Aid-to-Education grants are scheduled by the Foundation for 1959.

► Appplications for the National Science Foundation's Senior Postdoctoral and Science Faculty Fellowship programs are being accepted through Oct. 5th.

Members of the engineering sciences and others are eligible, provided they meet the following requirements:

Senior Postdoctoral Fellowship candidates must be citizens of the US with a special aptitude for advanced training. They must also have held the doctoral degree for at least five years, or have equivalent education and experience. A panel of scientists will make the final selection of the 75 fellowship recipients.

Science Faculty Fellowships are designed for college teachers of science, mathematics, or engineering, "who wish to improve their competence as teachers." The fellowships are open to any US citizen who holds a baccalaureate degree or its equivalent, has demonstrated ability and aptitude for science teaching and advanced training, and has taught at the collegiate level as a full-time faculty member for at least three years and intends to continue teaching. The National Science Foundation will select 300 Fellows to receive the grants.

A maximum stipend of $12,000 is awarded fellowship winners under both programs. Fellows may engage in study and/or research at any accredited non-profit American or foreign institution of higher learning. Some allowance for travel expenses is also available.

Application materials may be obtained from the *Fellowships Section, Division of Scientific Personnel and Education, National Science Foundation, Washington 25, D. C.*

► The International Nickel Co. of Canada, Ltd. is issuing a 39-min sound-color film depicting its operations. The film, the fourth of a series, is entitled *Refining Copper from the Sudbury Nickel Ores.*

Unusual shots of anode furnaces during poling operations, and the electric direct arc melting of pure copper are shown. Those parts of the process which cannot be photographed are presented in animation. Time lapse photography and color rear screen projection also enhance the 16 mm film.

Prints are available from *Rothacker Inc., 729 Seventh Ave., New York,* or *The International Nickel Co., Inc., 67 Wall St., New York.* No rental or mailing charge is assessed.

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Reply in confidence and detail to Donald J. Blackmore, Manager, Technical Personnel

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Engineering Teachers Boast Income Rise

The average professional income of engineering teachers in the US has risen 8.3 pct since 1956, and their basic teaching salaries have increased 13.5 pct, according to a survey published for the Engineers Joint Council. Their average professional income was $9598 in 1958, compared to $8862 in 1956. As for salaries, the survey showed that the teaching salaries of engineering educators ranged from $6744 in the South to $8392 in the Pacific region.

The Report, entitled *Salaries and Income of Engineering Teachers, 1958*, was prepared by the Bureau of Business and Economic Research at Northeastern University, Boston. Copies are available from the Engineers Joint Council, 29 W. 39th St., New York 18. Enclose 25 cents to cover costs of handling.

Index to Engineering Literature Available

Engineering Index Service provides libraries, industry, engineers, research workers, and students with the most complete analysis of all engineering fields available anywhere.

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Costs for the service range from $12 to $45 for an individual division to $1500 for the complete card service. Educational institutions receive a discount. An accumulation of all references throughout a year appears in bound form at each year's end. Cost of the volume is $70.

For additional information contact: *Ernest Hartford, Engineering Index, Inc., 29 W. 39th St., New York 18, N. Y.*

Seek Corrosion Papers for 1960 Conference

National Association of Corrosion Engineers is seeking papers on corrosion control for its 1960 Conference slated for Dallas, Tex., Mar. 14-18.

Titles and abstracts of the papers should be directed to the proper symposium chairman. D. W. McDowell, of the International Nickel Co., Inc., 67 Wall St., New York, is in charge of the Elevated Temperatures Symposium. The Protective Coatings Symposium is presided over by R. E. Gackenback, American Cyanamid Co., 30 Rockefeller Plaza, New York.

For further information on the Corrosion conference, contact: *National Association of Corrosion Engineers, 1061 M & M Bldg., Houston 2, Tex.*

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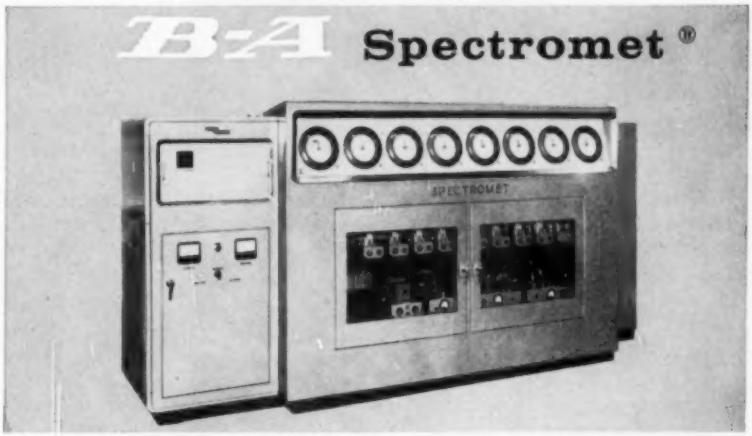

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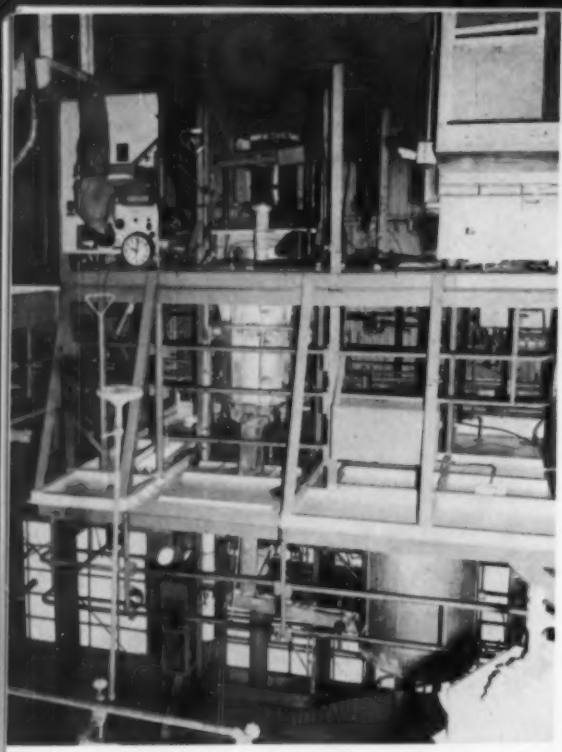


RAM REACTOR PROVIDES CONTINUOUS ZIRCONIUM PRODUCTION

by W. W. Dunham, Jr.

and R. D. Toomey

Just a year ago, first mention of this process was carried on JOURNAL OF METALS' *"Reporter" page. Here is the complete story—told by the men who developed the process.*

ZIRCONIUM production on a continuous basis, yielding reactor-grade zirconium or Zircaloy, with a high efficiency and low operating cost, has been the object of considerable effort and great sums of money. Just such a process has been developed at the laboratories of National Lead Co.'s Titanium div.

The new process for producing zirconium or Zircaloy ingots is built around continuous reduction of zirconium tetrachloride and periodic compacting and withdrawal of the metal product in a form suitable for arc melting. This is the key to high purity and lower production cost. The operation is called *the ram-reactor process,* taking its name from the hydraulic ram used to consolidate and push out the product.

Fig. 1 indicates process flow and equipment, starting with $ZrCl_4$ and ending with finished ingot. There are two steps to the process: 1) zirconium chloride reduction and 2) consumable-arc melting of compact. The operation in the first step, where the dense zirconium compact is formed, is continuous. Consumable-arc melting procedures, developed for sponge melting and modified to handle the ram-reactor process type of electrode, are utilized in step 2 where the final ingot is prepared.

Ram reactor reduction

Zirconium tetrachloride, received in standard drums, is charged into a vessel called a primary sublimator, where noncondensable gases and residues are separated. The purified charge from this primary sublimator is then vaporized and passed to a secondary vessel where conditions are controlled to allow a dense, solid, $ZrCl_4$ to collect on coils for subsequent transfer to the reactor. This method of handling the $ZrCl_4$ is a modification of that developed and reported by the US Bureau of Mines. The secondary vessel containing the dense, pure $ZrCl_4$ is located on a scale for rate control during primary transfer and subsequent vapor feed control to the reactor. For the continuous operation of the ram reactor, parallel vaporizers are provided, with one unit filling while the other is feeding. Low density, powder grade of purified $ZrCl_4$ has been sublimed directly to the reactor with good results, although the dense material on coils permits a more sensitive feed control and is of higher purity.

The ram reactor consists of a 6-in. tube, heated by a gas-fired furnace, with openings provided in the cover for the hydraulic ram, sodium or magnesium reducing metal, and purge gas venting. The lower portion of this reactor is filled with molten salt and the bottom is sealed by compacted zirconium metal. A salt overflow line near the top of the tube provides salt bath level control, and the feed inlet is situated below the salt bath level for introducing the gaseous $ZrCl_4$. The hydraulically-operated ram is brought down periodically to collect zirconium metal, which is formed in the bath, and to consolidate it into a dense compact at the bottom of the reactor. This increment of metal formed is pressed into the compact, which is withdrawn or expelled from the bottom of the reactor an equivalent distance to maintain a fixed level. Conditions of ram pressure, compacting zone temperature, and

W. W. DUNHAM, JR. and R. D. TOOMEY are with the Development and Engineering dept., National Lead Co., Titanium div., South Amboy, N. J. This paper was presented at the AIME Annual Meeting, San Francisco, February 1959.

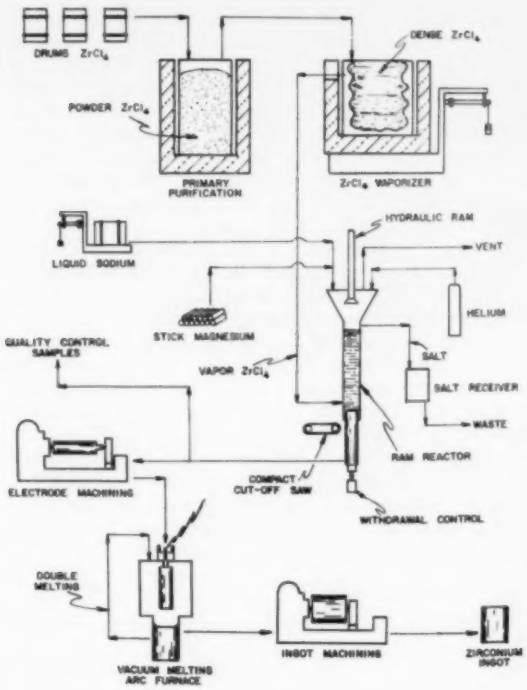


Fig. 1—Flow sheet for the ram-reactor process for producing zirconium ingot.

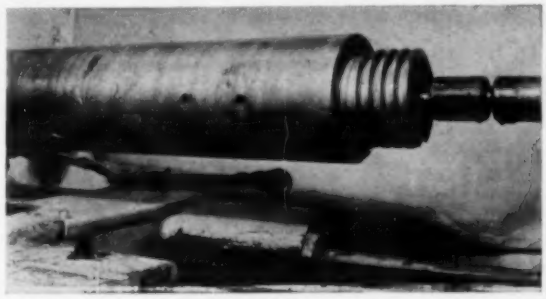


Fig. 2—Zirconium compact, showing thread for connection to the electrode holder in the furnace.

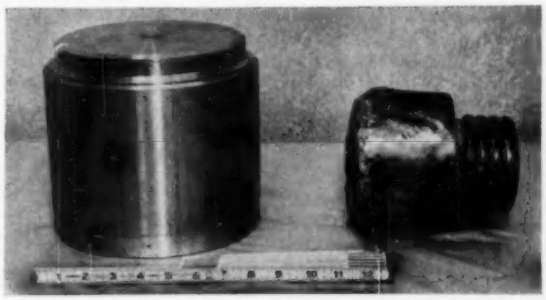


Fig. 3.—Primary zirconium ingot and the compact electrode stub.

withdrawal techniques have been developed to permit the dense compact to be lowered while maintaining a positive salt seal between the compact and the tube wall. The ram is then returned to its rest position above the bath level until another volume of metal has been formed. The by-product metal salt accumulated is displaced from the reactor to a salt receiver which is periodically tapped. The $ZrCl_4$ feed to the salt bath is continuous while the sodium, magnesium, or bimetallic combinations are fed intermittently during a feed period between rammings. The best results have been with bimetallic reduction, and this system has been standarized. Capacity of the molten salt bath to dissolve significant quantities of $ZrCl_4$ allows continuous feeding of this material without losses, and permits rather broad flexibility in procedures with high rates. The reaction takes place in the salt bath; thus, no losses as vapor phase product or as unreacted zirconium chlorides result.

The reliable operation of the ram reactor is best shown by the high operating factors obtained. During a recent series of consecutive runs the reactor was in operation with continuous $ZrCl_4$ feed an average of over 95 pct of the time, exclusive of feed preparation periods and weekends. High recoveries of zirconium in compact form are achieved in the reactor, since only limited quantities of soluble zirconium chlorides and insignificant amounts of zirconium metal particles overflow with the salt. Well over 90 pct of the zirconium in the $ZrCl_4$ charge is recovered as compacted metal. The very slight excess of magnesium metal which is maintained to insure complete reduction consolidates with the compact.

A unique feature of this continuous reactor is the addition of alloying metals to the reactor with the reducing metal. The homogeneity and alloy structure of Zircaloy-2 ingots made in this manner have been excellent. Compacts are periodically cut to length at the bottom of the reactor furnace and sampled for quality.

Description of compact

The zirconium metal compact consists of a dense, 6-in. diam cylinder of finely divided zirconium metal uniformly distributed in a matrix of salt and excess magnesium metal. The zirconium particles, normally less than 30μ in size, are compacted from a salt bath, which acts as the medium for the reaction between the $ZrCl_4$ and the reducing metal. When the compact of zirconium is lowered to the cooler underside of the reactor, the salt solidifies, thus forming a protective coating which allows removal of the zirconium metal from the reactor into open air with no contamination. A typical compact contains 91 pct Zr, 3 pct Mg, and 6 pct mixed salts (NaCl and $MgCl_2$).

The cylinder of compacted zirconium particles is not like compressed zirconium sponge, which has small areas of very dense metal and sizeable voids between these larger masses. In place of voids, the metal in the compact is consolidated with magnesium and salts. Density of the compact is 335 lb per cu ft, which is approximately 85 pct of that of pure zirconium metal, thus indicating that the metal particles are well compacted during preparation. Because of its structure and composition, this compact exhibits high physical strength and very low electrical resistance.

Arc melting

The compact is machined directly into a consumable electrode for arc melting. The compact structure of pressed metal particles in a salt matrix allows machining, drilling, grinding, and other handling with resulting fines and chips which are nonpyrophoric. There has been no other reduction process reported which produces zirconium metal in a form which can be handled with such a high dergee of safety. On the other hand, when the compact is turned in a lathe or sawed, the surface of the metal seals the salt sufficiently to enable the compact to be handled in normal atmosphere without excessive moisture pickup.

Fig. 2 shows the compact in the lathe where a thread has been cut for connection to the electrode holder in the furnace, and it illustrates the machinability of this material. Only a skim cut has been made along the compact length to remove the salt protecting layer exposing the bright surface shown. The holes shown are from drilling made along the compact length to obtain samples for quality control. These drillings are the only samples taken of the product before melting, which indicates the advantage over batch processes which require grading and blending of each batch. The electrode is now ready for melting to ingot.

The zirconium compact electrode is melted to a primary ingot in a consumable-electrode arc furnace of the type common to the reactive metals industry. Some changes in design, however, were required to handle the volatile salt and magnesium metal separated during melting. Modifications include expanded throat volume above the crucible, salt traps in gas lines, and a sufficiently large pumping system to handle gas bursts. The compact is of sufficient density that no problems with electrical conductivity have ever been encountered. Current densities up to 300 amps per sq in. have been used. Electrode strength during melting has also been satisfactory with electrodes over 4 ft long weighing up to 250 lb having been melted. Short electrode sections have been coupled by threading to form longer electrodes and have been melted with no problems at the joints.

The primary ingot resulting from the compact melt normally contains a salt and magnesium skin on the wall surface which is next to the cold copper moid. Otherwise the ingot is sound and satisfactory for remelting. The splatter ring, which also contains some residual salt, is cut away, and the ingot is machined to bright metal. The primary ingot is free of salts and magnesium with less than 100 ppm of these impurities. These ingots are coupled together with threaded zirconium studs to form the consumable electrode for the secondary melt. The conditions for this vacuum remelt are similar to those standardized in the industry and the same equipment is used as for the primary melt. A vacuum of from 10 to 40 μ is used for this remelt which results in a sound ingot of high purity. The standard primary ingot size, which has been prepared from the 6-in. compact, is 9 in. in diam, and the remelt ingot, ready for forging, is 11½ in. in diam. Fig. 3 shows a primary ingot and the compact electrode stub.

Table I. Ram Reactor Zirconium Ingot Composition, Impurities in Ppm

Oxygen			<300
Nitrogen			<30
Carbon			<30
Hydrogen			<10
Hf	60	Mg	<10
Cd	<0.5	Ti	<20
B	0.3	Zn	<50
Al	20	Mn	<10
Fe	300	Mo	<10
Cu	<20	V	<10
Cr	30	Ni	<50
Si	<20	Ca	<20
		Sn	5

Ingot quality

Quality of zirconium ingot produced from this process is superior to any Kroll process material reported to date, and is equivalent to crystal bar metal in ductility. Typical analyses for reactor-grade zirconium final ingot are given in Table I. Equivalent levels of purity have been maintained with Zircaloy-2 ingots. Evaluation of both grades of ingot have been made by others with excellent results. Forging and rolling properties of a large zirconium ingot were considered to be exceptionally good. Strips of sheet have been rolled from 0.062 to 0.001 in. without intermediate annealing. Corrosion testing on Zircaloy-2 specimens indicated excellent corrosion resistance in pressurized hot water.

Process economy

The cost of zirconium metal in a commercial unit, which would produce an 8-in. diam compact, has been estimated to be considerably lower than the present cost of batch Kroll type ingot for the following reasons:

1.) Equipment costs are lower than for batch type units; one 8-in. diam ram reactor can produce as much zirconium metal as several standard batch Kroll units.

2.) Elimination of several process steps reduces cost and improves quality. The operations eliminated are: a.) salt distillation or leaching, b.) batch removal of sponge by chipping or boring, c.) crushing, grading, blending, and packaging sponge ,and d.) pressing and welding of electrodes. Obviously, labor saving is realized with these steps omitted.

3.) The process yields of materials are excellent. For examlpe, well over 90 pct of the zirconium values charged to the reactor is extruded as electrode material. With only a slight excess of magnesium required in this reactor, additional material savings over batch processes are evident.

4.) In addition to high reaction yields, further economies can be realized with the direct recycle of electrode and ingot turnings as machined. With other processes, the product impurities are not sufficiently below specification levels to permit this. Extremely low impurity levels of ram reactor ingot, for example, oxygen <300 ppm, permit recycle of most of the machining chips to the reactor while maintaining the AEC specification limits with ease.

5.) A potential advantage of the process would be the utilization of scrap metal from other sources. Chopped pieces of low-cost scrap material, surface cleaned by pickling or sand blasting, can be added to the reactor in reasonable quantities to be pressed into the compact with the virgin metal and melted in the regular manner.

Other advantages of the ram reactor process, such as alloying within the reactor, reduced quality control requirements, and reduced space requirements are also attractive for economy reasons. The process is not exclusively used for zirconium—other metals of similar high quality have been prepared in the ram reactor.

ZIRCONIUM BY SODIUM REDUCTION

The story of the production of reactor-grade zirconium at one of the largest and most modern zirconium plants, the Ashtabula, Ohio, plant of Mallory-Sharon Metals Corp.

by F. Weston Starratt

DURING the past few years many problems have been solved in order to achieve commercial-scale production of reactor-grade zirconium. Probably one of the most difficult of these was the separation of zirconium from the closely-related metal, hafnium, which follows it—almost without exception—through most chemical processes. Separation must be achieved for either metal to find application in the atomic energy field. In regard to neutron capture characteristics, these two metals are directly opposite; zirconium having one of the lowest neutron cross-sections, and hafnium one of the highest—500 times that of zirconium.

Several years ago, through its pilot plant at Albany, Ore., the US Bureau of Mines undertook to solve the problem of zirconium and hafnium separation. The resulting process was further developed by the AEC at the Oak Ridge National Laboratory, and it has been put into commercial-scale operation at several plants. The largest such operation is the 2-million-lb per year plant of Mallory-Sharon Metals Corp. at Ashtabula, Ohio. It is not merely a scale-up of the US Bureau of Mines process, but it contains a number of unique features. The plant produces only reactor-grade zirconium, containing less than 100 ppm of hafnium.

The process in outline . . . purification

Raw material for the Ashtabula plant is zirconium tetrachloride, a powder which—because of its highly reactive nature—is transported by truck in large nitrogen-filled bags from Stauffer Chemical Co.'s plant at Buffalo, N. Y. Each bag holds 6 tons of tetrachloride.

The first series of operations is designed to remove two impurities—iron and aluminum—and separate hafnium. This results in a pure zirconium oxide, which is re-chlorinated and then reduced to reactor-grade metal, conforming to US Atomic Energy Commission specifications.

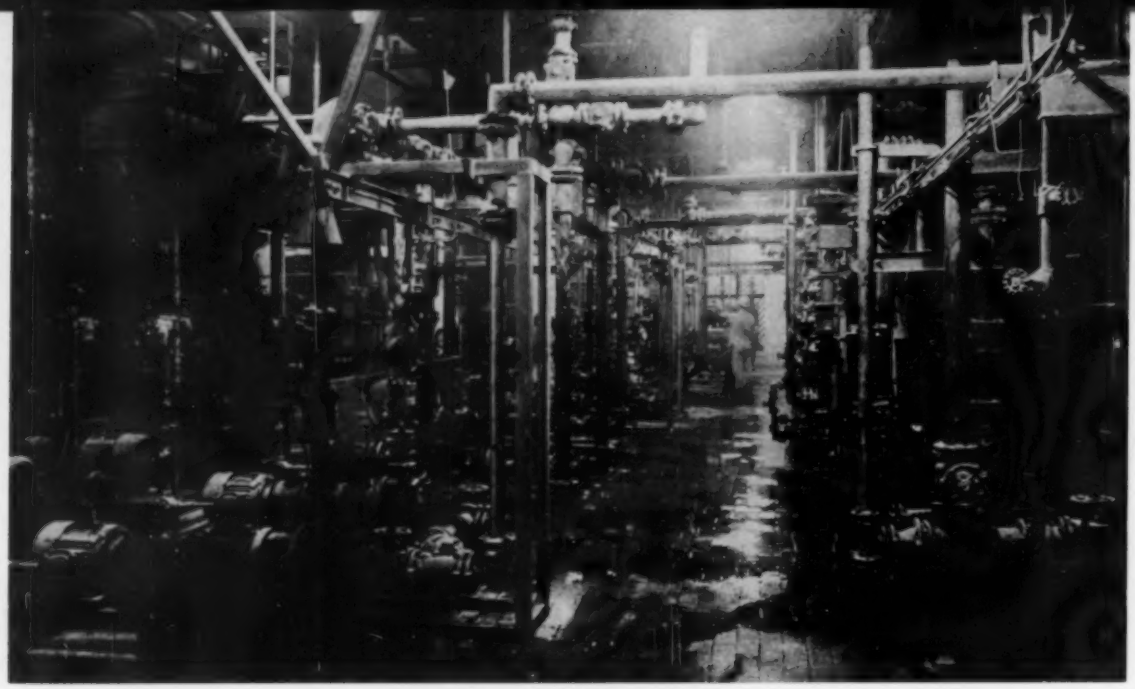
Dissolved in water . . . the first step is to remove iron from the impure zirconium tetrachloride. This is accomplished by liquid-liquid extraction in tall columns containing a series of glass baffle trays. Methyl isobutyl ketone is used for the organic stream, carrying the iron along with it and reducing the iron content in the zirconium stream to less than 1 ppm.

Liquid-liquid extraction is also used for the separation of hafnium from zirconium. This operation takes place in vertical columns similar to those used for iron removal. The organic stream is again ketone, but this time ammonium thiocyanate is added to assist in the separation. This technique has proved successful in reducing the hafnium content in the zirconium stream to less than 100 ppm.

Aluminum separation is the next step. It is a tricky operation accomplished by precipitating zirconium as a sulfate under close pH control at a level of about 1.5. Aluminum remains in solution. The zirconium sulfate is removed and then treated with aqueous ammonia to produce zirconium hydroxide, which is filtered and washed, repulped, and finally calcined in a rotating circular kiln to produce reactor-grade zirconium dioxide.

This is an intermediate point in the process, since zirconium dioxide is a non-reactive material, capable of being stored and transported without danger. It is a very important check point, for by careful control of the zirconium dioxide, the purity of the metal itself can be insured.

Up to this point in the process, corrosion is a major problem. In many cases, valves and pipe lines are capable of withstanding the highly corrosive fluids for only a few weeks. Many of the pipe lines, and in fact the liquid-liquid extraction columns themselves, have been made of a material—a mixture of asbestos and a plastic—by the trade name of Haveg. It has successfully withstood the corrosive conditions, but is is extremely brittle and is relatively high in cost. Valves made of various corrosion-resistant alloys have not, in general, proved satisfactory; so, Mallory-Sharon is now using valves made of their highly corrosion resistant metals—zirconium and hafnium. Such valves, actually made in the machine shop of the Ashtabula plant, demon-



General view of hafnium separation area.

strate the excellent corrosion resistant qualities of tnese two metals by lasting almost indefinitely, even under the conditions encountered in the purification section of the zirconium plant.

. . . chlorination and final purification

Metallic zirconium is produced by the reduction of the tetrachloride; hence, the purified dioxide must pass through a chlorination process. The dioxide is mixed with carbon black, briquetted, and charged into an electrothermic chlorination furnace, wherein the carbon acts as a conductor of the electric current. Gaseous chlorine is introduced into the furnace, and zirconium tetrachloride passes out of the furnace as a vapor, which is subsequently condensed.

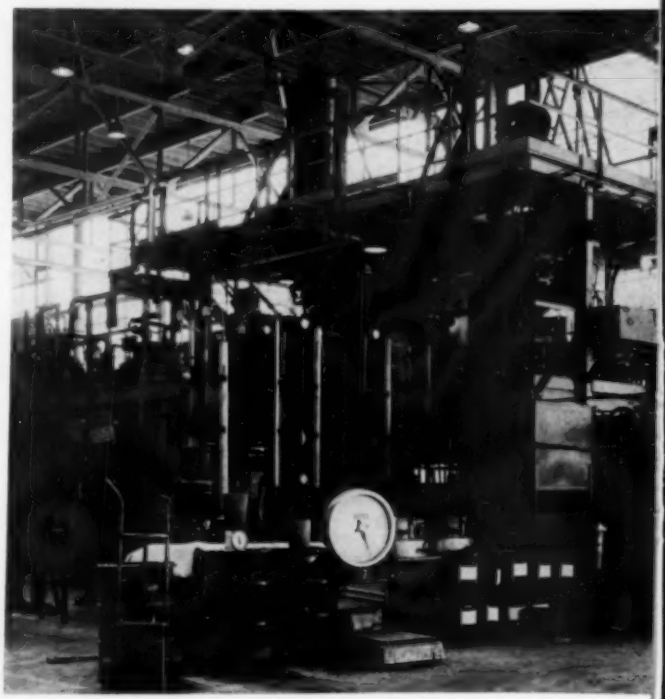
Up to this point, the process has largely followed that developed by the US Bureau of Mines, but the purification step through which the tetrachloride now passes is an exclusive development at Ashtabula for the production of the highest purity product. In this step the tetrachloride is charged into a molten salt bath. The resulting salt mixture is pumped to a vaporizer where the zirconium tetrachloride is vaporized and then condensed in another vessel. The depleted salt mixture—containing impurities from the zirconium tetrachloride—is returned to the first tank. A certain amount of the liquid salt mixture is continually bled off in order to maintain the purity of the mixture within satisfactory limits. The purge is reclaimed.

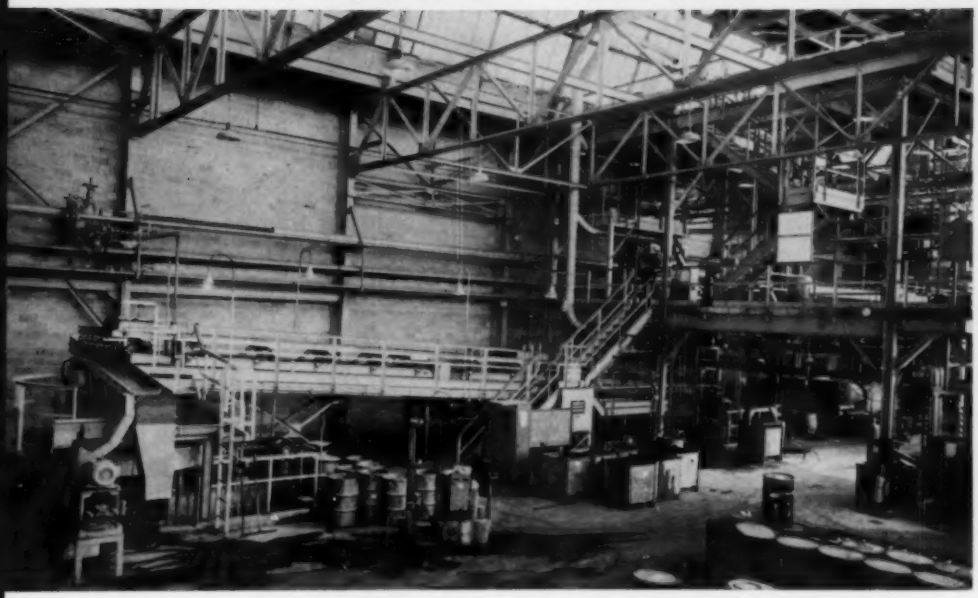
. . . sodium reduction process

Whereas most other plants use a magnesium reduction operation, Ashtabula makes use of what is claimed to be a lower-cost sodium reduction step. In fact, one reason for the location of the zirconium plant at Ashtabula, Ohio, is that the industrial complex of that region includes a sodium plant of U.S. Industrial Chemical Co. Not only is sodium received from U.S.I., but that plant's chlorine is also used in the chlorination of the zirconium dioxide. Salt brines from the washing of the zirconium sponge are returned to the U.S.I. plant.

Sodium received at the Mallory-Sharon plant is triple filtered and stored prior to use. It is pumped as a fluid to the reduction furnaces in pipe lines heated by induction coils wound around them. Sodium is introduced to the zirconium tetrachloride in an inert-atmosphere holding vessel prior to being pumped into one of the series pots which are moved to furnaces where reduction takes place. Care must be taken in the entire operation because of the highly reactive quality of the materials involved,

Drip melting zirconium sponge.





Equipment for crushing, leaching, and drying sponge. Below, hardness testing of zirconium evaluation ingots.

and the exothermic nature of the sodium reduction process.

Reduction is a batch operation, which takes place in large-size pots made of heavy welded steel plate. Such pots are sand blasted prior to each operation in order to insure that no foreign matter is introduced. The lids are welded on and tested by pumping high-pressure argon gas into the vessels. This argon atmosphere is maintained until the sodium and zirconium tetrachloride mixture is pumped in. The pots are then placed in the floor furnaces and heated to several hundred degrees, at which point the reduction reaction proceeds exothermically, raising the pot to red heat. After several hours of soaking, the pots are removed from the floor furnace, allowed to cool, and then opened. A rock drill is used to break the resulting mixture of zirconium sponge and rock salt out of the pot. The sponge-salt mixture from the pot is crushed and thoroughly washed so as to bring the salt content down to 1 pct of the total material.

The crude zirconium sponge is now subjected to another process which is unique to Ashtabula. This is a drip melting operation, designed to remove the last traces of salt and produce *chunklets* of metallic zirconium which—because of their reduced surface area—do not pick up moisture and have no pyrophoric tendencies. The sponge is compacted into an electrode, which is fed into an inert-atmosphere induction furnace. The salt is vaporized and the zirconium drips onto a cold, rotating wheel which throws the metal off in the form of chunklets. These are subsequently packed in 500-lb barrels for shipment.

Careful chemical and spectrographic tests are made of each batch of zirconium, and an evaluation ingot is made and checked for composition and hardness.

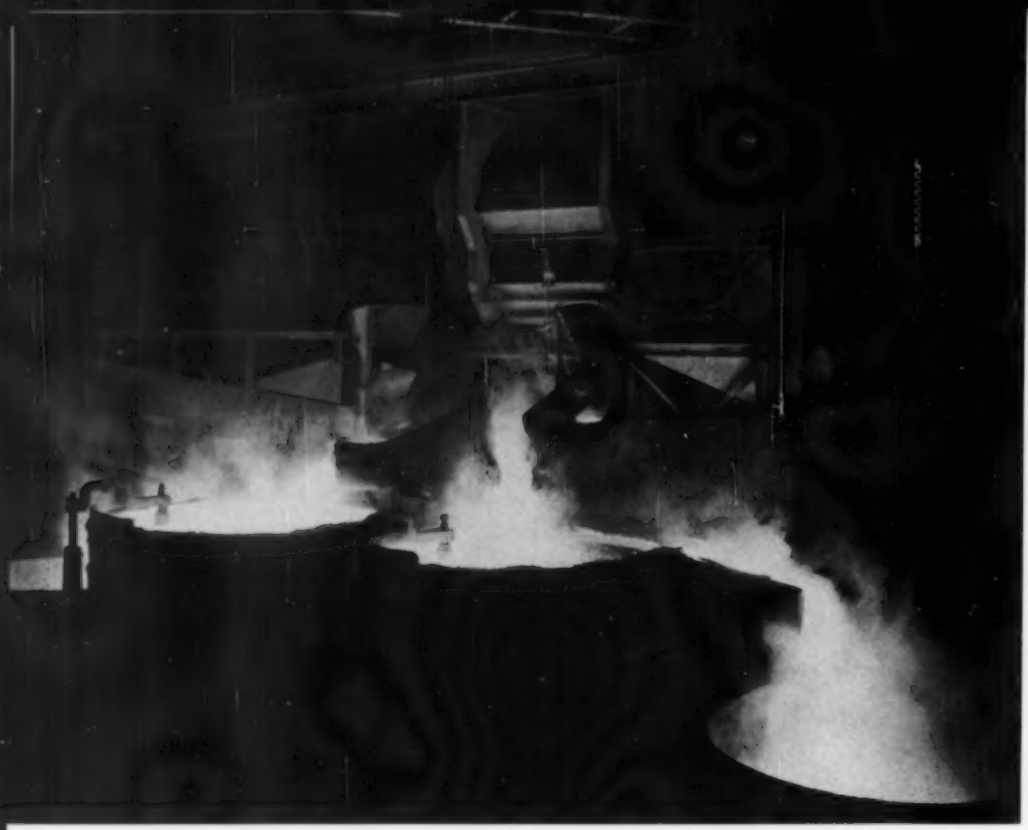
Hafnium production

The crude zirconium tetrachloride entering the Ashtabula plant contains about 2 pct Hf, which, as has already been described, is separated from the zirconium by liquid-liquid extraction. This hafnium follows the same steps as does the zirconium, only in a smaller scale operation. It is sold as hafnium dioxide—96 pct pure—and is not further processed by Mallory-Sharon.

Conclusions

Impressive is the word to describe the modern Ashtabula plant for the large-scale production of zirconium as well as titanium. Equally impressive are the problems encountered in the processing of the highly corrosive and reactive materials involved. In practice, the process requires numerous steps and much equipment. Extreme care must be exercised at every turn. And after visiting the plant, it is not difficult to see the reasons for the high cost of the product. One might even ask, "Why is it so cheap?"

There can be no doubt that reactor development will increase greatly in the next few years, but the high cost of materials leaves their ultimate place in the reactor field still to be determined. Establishment of a broader base for the use of zirconium will go a long way toward insuring a larger output and consequent lower costs.



Tapping a 600-ton heat from the world's largest open hearth, at Weirton Steel Co., div. of National Steel Corp., Weirton, W. Va.

STEELMAKING / U.S.A.

This is the fourth and final installment of Leo Reinartz' summation of the steelmaking industry over the first one hundred years.

by Leo F. Reinartz

ALTHOUGH basic open-hearth steel has been in the limelight for many years, it has had to share some of its glory with two lesser but nevertheless important rivals, one 50 years old and one a rejuvenated process.

Electric steel

Electric-steel manufacture began in a humble way in the United States in 1906, when the first heat was tapped from a 3-ton Heroult electric furnace at the Halcomb Steel Co., Syracuse, N. Y.

During the intervening years, it has completely eliminated the crucible process. For many years electric melting furnaces were located predominantly in relatively small, nonintegrated plants, making all kinds of high-grade alloy steels. Most of these furnaces, with capacities ranging from 5 to 20 tons, had basic bottoms. During and after World War II, many large basic electric furnaces, some up to 200 tons in capacity, were installed in integrated plants to make commodity steels.

There were several reasons for building electric furnaces. Capital investment per annual ton of capacity was low and furnaces could be installed quickly. Since these furnaces used mostly scrap iron in the charge, no extra expensive coke- and blast-furnace capacity had to be added. The perfection of the top-charging design, and the development of large transformers and furnaces, made possible tons per hour as high as from modern 350-ton open-hearth furnaces.

Electric furnaces have high availability and repair costs are low. The process is flexible. Alloy and plain carbon steels of high quality can be made. Where power costs are low, the operating cost can

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approach that of the open-hearth, especially if all-cold-metal shops are being compared.

The process has several serious handicaps. Because of the high scrap charge, the total ingot cost is subject to the vagaries of the scrap market. Electric furnace ingots contain most of the tramp nonferrous metals that come into the charge with the scrap iron. Recently a new process for scrap iron preparation, developed in the southwest United States, indicates it can materially reduce the percentage of tramp nonferrous materials. Costs of electric power are high in many parts of the US.

The rated capacity of the electric furnace melting units on Jan. 1, 1959, was 13,495,130 net tons, or a little less than 10 pct of the annual US steelmaking capacity.

It is interesting to note that during the past 25 years, the bessemer steel capacity of the country has declined, until, on Jan. 1, 1959, its rated capacity, excluding oxygen converters, was only 3,577,000 net tons, or 2.4 pct of the total US steelmaking capacity. The greater part of this production is used as blown metal in open-hearth furnaces as part of the duplex process. The steel resulting from this practice is apt to be high in nitrogen and, therefore, not suitable for certain uses of high-grade steel.

The LD process

Not until 1950 did another process for making steel come into the picture. In that year a pneumatic process using pure oxygen as a fuel was started in Linz and Donawitz, Austria, soon known in the United States as the LD process. High-purity oxygen at high pressure (150 psi) was blown from above onto hot metal and scrap iron, which had been charged previously into a basic-lined, solid-bottom bessemer-like vessel. The charge could be melted and refined in about 40 minutes.

Capital expenditures to build such a plant were relatively low; steel of good quality, low in sulfur, phosphorus and nitrogen, could be made very rapidly at lower operating costs than in open-hearth furnaces. Depending on the silicon content and temperature of the hot metal, scrap iron up to 35 pct of the total charge could be added.

Since then, in North America, Dominion Foundries & Steel Co., Hamilton, Ontario, Canada, and McLouth Steel Co., Detroit, have installed, and are successfully operating larger LD units. Late in 1957, Jones & Laughlin Steel Corp., began operating the largest LD converter in the US, at Aliquippa Pa. Algoma Steel Co., and Kaiser Steel Corp., began to operate units having capacities of from 90 to 100 tons, during the latter part of 1958.

These converters are expected to produce 80 to 100 tons per hour, thus becoming the highest tonnage producers in the steel industry. Acme Steel Co. has recently built a combination hot-blast cupola and 40 ton oxygen converter system of new design.

Jones & Laughlin Steel Corp. has announced plans to build a new LD plant at their Cleveland works. Converters will have a capacity of at least 160 tons.

Other pneumatic oxygen-furnace units have been developed in recent years in Europe, particularly to melt and refine high-phosphorous hot metal; namely, the *Kaldo* process in Sweden (see JOURNAL OF METALS, July 1957, p. 972) and the *Rotor* process in Germany (see JOURNAL OF METALS, November 1957, p. 1435). Since these processes do not seem to be adaptable to American practice at this time, they will not be discussed here. It may be that some day in our country one or the other of these processes may be adapted to desiliconize and decarburize hot metal for speeding up open-hearth and/or electric-furnace production.

Notable steel companies

During the second half of the 19th century, numerous small, independent steel companies, some of which have been mentioned herein, were organized and began to operate in a number of cities east of the Mississippi River. Some of them operated for a while quite successfully, but adversities in the form of recessions, prolonged strikes, changes in steelmaking processes or practices, constantly cropped up. Those were days of ruinous, cut-throat competition. Many companies fell by the wayside or, with bewildering swiftness, were swallowed up by changes in ownership. There was no stability in steel markets. One wonders how any of them ever prospered.

It is not within the scope or the province of this paper to chronicle in detail the developments of basic steelmaking in each of those companies. However, it is desirable to mention the beginning dates of some major steel companies in our country, together with the names of the stalwart, courageous, and forward-looking men who had the most to do with bringing them into existence.

During the nineties

During the decade of the 1890's many discussions on how to bring order into the chaotic steel situation took place. Joseph E. Block and associates decided to organize the Inland Steel Co., Chicago, in 1893. The Indiana Harbor Works was built under the leadership of L. E. Block in 1901.

The Colorado Fuel & Iron Co., founded in 1872, was reorganized in 1892. Its main plant is at Pueblo, Colo. Its predecessor, the Central Colorado Improvement Co., in Denver, was incorporated by a man of vision, General William J. Palmer.

Armco Steel Corp. was incorporated in 1899. Under the benevolent leadership of George M. Verity, it started in a very small way in 1901 as the American Rolling Mill Co., at Middletown, Ohio. In 1930 it took over Sheffield Steel Corp. The name was changed to Armco Steel Corp. in 1948.

Republic Iron & Steel Co. started operations in 1899 at Youngstown, Ohio. In 1930, with the dynamic leader Thomas Girdler at the helm, Republic Steel Corp. was organized. Central Alloy, Donner, Bourne-Fuller, and Witherow steel companies, and the Interstate Iron & Steel Co. were merged with the Republic Iron & Steel Co. to form this corporation.

Late in the 1890s, a number of bankers, lawyers, and steel men decided that the times were propitious for the formation of a large steel corporation. Their object was to produce steel more efficiently and economically by what has since become known as integrated operations. They hoped to help bring greater stability to the steel markets.

Turn of the century

A few years prior to 1900, Judge Elbert Gary had been responsible for the formation of the Federal

Steel Co., in Chicago. J. Pierpont Morgan and John W. Gates, noted New York bankers, also were interested in the formation of a large steel corporation that would have under its control all the operations from mine to markets. This combine, they hoped, would operate iron-ore and coal mines, limestone quarries, iron-ore shipping facilities, steelmaking, and fabricating plants.

Charles M. Schwab was a rising young steel magnate, who had become president of the Carnegie Steel Co. in 1897. He interceded with Andrew Carnegie, the colorful steelmaker of Scotch descent and principal owner of the company, to sell his interest in the Carnegie Steel Co. to the proposed combine headed by Judge Gary.

Thus in 1901, the giant US Steel Corp. was organized, joining the Carnegie companies with the Federal Steel Co. and others to form the first billion dollar corporation in the world. Mr. Schwab was elected as the first president, and Judge Gary became the first chairman of the board.

Among the original members of this combine were American Sheet & Tin Plate Co., American Bridge Co., American Steel Hoop Co., American Tin Plate Co., Lake Superior Consolidated Iron Mines, National Steel Co., and National Tube Co.

In 1902 Schwab severed his connections with US Steel Corp. when he bought controlling interest in the Bethlehem Steel Co. which, in its present form as Bethlehem Steel Corp., began its principal operation at Bethlehem, Pa., in 1905 with Schwab as president.

Crucible Steel Co., under the guidance of W. P. Snyder, consolidated a large number of small plants (many in the Pittsburgh area) in 1900 to form the Crucible Steel Co. of America. In the same year James A. Campbell was the dominant spirit in organizing the Youngstown Sheet & Tube Co. in Ohio. Sharon Steel Hoop Co. began operations at Sharon, Pa., in 1900.

Pittsburgh Steel Co. started its plant at Monessen, Pa., in 1901. Four years later, the Allegheny Steel Co., later to become the Allegheny Ludlum Steel Corp., began operations at Brackenridge, Pa.

Weirton Steel Co. was organized by Ernest T. Weir and associates in 1905, when it began operations at Clarksburg, W. Va. In 1929, Weir incorporated this company into the National Steel Corp., with its principal plants at Weirton, W. Va., and Detroit.

In 1912, the Laclede Steel Co. was started by T. R. Akin at Alton, Ill.

The latest of the dynamic steel leaders to start a major steel company is Henry Kaiser. His Kaiser Steel Corp. began operations at Fontana, Calif., in 1942.

Men of vision

The rapid strides made by the steel industry in the past 50 years have been due to the leadership and optimism of men of vision, energy, skill, and great courage. They were willing to explore the unknown at the risk of capital and ruin itself. They knew how to exploit the almost inexhaustible natural resources of our country. They were enterprising men who were willing to risk and spend large sums of money to find cheaper and better methods of steel production and manufacture. Last, but not least, they had a true love for their fellowmen—the workers in their plants.

Because of this interest in human beings, they encouraged plant managements and supervisors to improve the lot of the steel worker with better lighting, sanitation, and protection against heat and cold. Because of their zeal for accident prevention, the improvement in the safety record of American steel plants during the past 10 years has been truly remarkable.

In all the technical advances of recent years, the producers of steel ingots have played the star role; without quality steels in great tonnages, this marvelous progress could not have been made. Results became possible only because of the conscientious, patient, and efficient work of countless thousands of steel managers, supervisors, engineers, metallurgists, mechanics, furnace operating and repair crews, as well as the expenditure of hundreds of millions—yes, billions—of dollars invested by the boards of directors of the steel industry for the improvement of old furnaces and accessories, and for building new ones—bigger and better than ever—as well as developing new processing and finishing equipment to fabricate these ingots into commercial steels.

It has been estimated that 30 pct of the gain in ingots has come from modernization programs and 70 pct from newly installed units. Each year the horizon is pushed back as larger furnaces go into production.

Predictions

The end of this race in size may be in sight. I predict this time will come sooner than some expect, not because of the lack of efficiency or because of increased operating costs of these monsters, but simply because of economics. Like the increased capital cost of building coke ovens and blast furnaces, the capital cost per annual ton of capacity for building new, big, open-hearth furnaces is now higher than the cost of building other newer types of furnaces and processes to produce ingots, such as the pneumatic oxygen converters or large electric furnaces.

During recent years, predictions have been made freely that by 1975 the increasing requirements of American citizens will demand a capacity of steel ingots of close to 180 million tons. Every prospect pleased the steelmakers.

Then in the fall of 1957 and the early part of 1958 came an awakening. Steel production, owing to decreased demand and inventory reductions in customer's shops and other causes, dipped down to less than 60 pct of capacity. It appeared that the US, after a tremendous economic sprint, had slowed down and was taking a breathing spell. For the first time in many years, the steel industry had a considerable excess steel capacity.

However, there was little reason to believe that this recession would be of long duration. The long-time trend, because of increasing population and wants in the US, seemed to indicate that an upward surge of ingot capacity could again be expected in the next few years.

In the future, competition in the US and from abroad will continue to be keen. Progress must continue to be made in open-hearth shops to increase production from its furaces, old and new.

Future open hearth plants

Suffice to say, the great bulk of steel requirements in the US within the next 10 or more years will be made in the basic open-hearth furnaces.

Open-hearth shops will be redesigned to decrease the effects of weak spots or bottlenecks in the system. Furnace refractories and quality of brick will be improved. This will be true also of bottom and bank construction and furnace maintenance.

As long as ambitious, imaginative open-hearth supervisors exist, they will continue to lengthen, widen, and deepen present furnace hearths. Thus they can tap larger heats, if conditions permit, into one ladle, or into two ladles through a bifurcated spout. It is well known that a 1 pct increase in heat size can give an increase of 0.5 pct in tons per hour.

With driven fuel, and by increasing the Btu consumption per hour for faster melting, it is possible to raise open-hearth roofs considerably without an increase in fuel consumption.

The all-basic furnace, I predict, will become a standard design in a few years Basic roofs may be flat or arched. I believe that high, flat, suspended basic roofs will replace silica brick roofs.

By the use of elevators, large scrap cars (as in the Calderon system) or by the improvement of present equipment and practices, prepared scrap iron will be charged from large pans into the furnace to bring the average charging time down to an average of one hour in hot-metal shops and to less than three hours in cold-metal shops.

Oxygen will be used with liquid or gaseous fuels through corner, end, or roof lances to speed up melting and refining steel. Thus, firing rates will continue to increase with more tons per hour and lower Btu per ton. In the not-too-distant future, average figures for hot-metal shops should be down to 3 million Btu per ton. Some modern shops will go considerably below 2.5 million Btu per ton.

This practice can be reached by paying more attention to proper combustion control. Higher preheat of the incoming air will be assured by better checker chamber gas flow, better checker refractories, improved sealing, and insulation of the entire furnace system below the charging floor level.

Two-pass checker construction will become more popular. The first pass of such checkers will be capped with 12 to 18 courses of highly-refractive brick. Fantails will be of basic design. Soot-blowing installations and methods for the rapid removal of deposits from the *blind* pass and from between the rider walls under the checkers will be standard practice. First-pass checker temperatures will be kept in close control by radiation pyrometers.

The furnace and its auxiliaries will be completely regulated by the use of automatic combustion and furnace reversal controls, tied in with continuous sampling and analysis of waste gases leaving the furnace hearth.

It must be realized that trained staff combustion engineers will be a great help to operators in meeting these objectives.

In furnace operations, flushing practice, where it continues to exist in hot-metal shops, will be carefully controlled, regulated, and speeded up. I visualize, however, the elimination of this messy time and labor-consuming practice. The hot metal will be top blown with high-pressure oxygen in a transfer ladle, or in some other kind of intermediate vessel. All the silicon and most of the carbon and siliceous slag will be removed quickly before the hot metal is poured into the open-hearth furnace. Such practice will assure higher hot-metal temperature and a considerable decrease in the amounts of limestone and expensive iron ore charged into the furnace.

Open-hearth production will be greatly increased and conversion costs lowered. In addition, in order to help increase monthly shop production, furnace repairs must be carefully planned, scheduled, and speeded up. This can be done by the use of many labor-saving devices, by increased skill and interest in bricklaying, and by faster tear-down and heat-up times.

Trained staff metallurgists will be required to assist furnace operators in devising better methods and practices to control metal and slag temperatures and reactions throughout the refining period. Final slags will be brought into closer equilibrium with the metal. Average sulfur content in the finished metal will be lowered by the use of better raw materials and improved furnace practices. Instruments will give better control of final carbon analysis.

Pit practice will be improved. Mud in runners and ladles will be entirely replaced by better refractories. Teeming practice can and must be improved. When more information is gained relative to the flow of molten metal through nozzles, I am sure a mechanism can be developed to lower the ferrostatic pressure of the metal without loss of stream regularity as the metal enters the mold. Such an improvement will help to decrease the quality hazzards of metal splash on mold walls. Nozzles up to 18 in. long will help solve this problem.

With improved metal-temperature controls, mold life will be longer, steel stools with cast-iron inserts will be developed to decrease costs of stools.

The importance of people

The open-hearth superintendent must depend mostly on people for the successful operation of a shop in the economical production of quality steels.

Brick, mortar, and steel are important to provide buildings, furnaces, and equipment, but they are lifeless and useless until actuated by the hands, minds, and I might add, hearts, of enlightened managements, and intelligent, cooperative workers.

Management will pay more attention in the future to the proper training of supervision, techical staff, and furnace crews. They will be taught how to produce quality products at low costs in a friendly atmosphere of cooperative effort. They will be shown how to obtain maximum tonnage from existing facilities. All will be encouraged and will become interested in making suggestions for improvements in equipment and practices.

Plants will have proper lighting, sanitation, and other working conditions. Wages will continue to be paid that will be adequate to enlist the best efforts of open-hearth personnel.

Future changes

There are a number of ways in which steelmaking may be changed in future years:

1) Oxygen LD converters, because of their low capital cost per annual ton of capacity, their flexibility, low operating costs, and acceptable qual-

ity, will probably be installed in integrated plants. Steel ingots that can be delivered hot, at frequent intervals, to the soaking pits, will increase the efficency of such pits, and help increase tons per hour through rolling mills.

2) Electric melting furnaces will continue to increase in size. Furnaces of 300 tons capacity, having six electrodes and transformers with large capacity are possible. Here again, the capital cost per annual ton of capacity is considerably less than for similar output from open-hearth furnaces.

In addition, coke plant and blast furnaces, under certain conditions, may not be required for the economical operation of electric furnaces. In non-integrated, cold-metal shops, present day modern electric furnaces can hold their own with open-hearth furnaces in ingot cost per ton and in quality.

In comparison with hot-metal open-hearth practice, electric furnaces have two serious handicaps:

a) As stated before, electric furnaces in most shops are charged almost entirely with scrap iron. As a result, contamination from nonferrous metals in such scrap is a serious quality hazzard. Prolerized scrap process may help to solve this problem.

b) Ordinarily no hot metal is used in electric furnaces. The ingot cost, therefore, is subject to the violent fluctuations of the scrap market prices.

If hot metal is available in an integrated shop, in the future it may be externally desiliconized and partially decarburized by the use of oxygen. Such *wash* hot metal can then be safely charged at least up to one half the total charge into modern top-charged electric furnaces. By the use of such a practice, the already high tons per hour can further be increased. By including capital charges in cost comparisons, ingot costs usually can be brought into line with average prevailing open-hearth costs.

3) Within the next 10 years, processes will be developed to produce high-grade sponge iron, especially in favored areas, to compete favorably in limited percentages—up to 50 pct—with scrap iron charges in open-hearth furnaces.

In shops where capital funds are not available for building additional, expensive coke ovens and blast furnaces, sponge iron, up to 60 pct of the total charge, may be charged into modern, top-charged electric furnaces. The sponge iron should be compressed immediately after manufacture into briquettes having a density of over 200 lb per cu ft. This practice will assure better furnace operation and normal tons per hour compared to average scrap iron charges. If the sponge iron contains 90 pct iron and less than 3 pct gangue, ingot costs should be comparable to those of average scrap practice. The absence of nonferrous contamination in sponge iron will improve the quality of the resultant steel.

4) It is entirely possible that some enterprising individual in the future may substitute a number of oxygen lances in the roof of a large electric furnace to melt the charge and then refine the steel with electric power. Such furnaces might be 25 ft or more in diameter, having a high basic roof, equipped with large vents for fume removal.

5) With improved methods for keeping checkers clean, as well as the modern technique of sealing and insulating, together with adequate forced-draft control, we might change the design of existing open-hearth furnaces. The present slag pockets and checker chambers could be used as enlarged dust and fume-settling chambers. They would be connected on the outside to three vertical stoves, similar to those on blast furnaces. Two stoves would be in operation and one in reserve or on repair. Furnace availability and repair costs might be improved, which means more tons per campaign.

6) Future requirements for rolling and improved quality may make it desirable for steel men to vacumn-melt or cast high-grade forging-quality, high-carbon steels as well as certain alloy and stainless grades.

7) Multiple casting machines will be perfected within the next 10 years, to cast billets and slabs at a rate high enough to justify their use in some plants for special steel manufacturing.

8) If nuclear power can be harnessed some day to provide heat for use in steel melting furnaces, we may see a radically different type of furnace. It may usher in a new era in steel manufacture, undreamed of today, in which steel of uniform quality may be produced at fantastic rates.

Conclusion

The best thoughts on the design and efficient operation of present and new basic-steel melting and refining furnaces will be required by American steel producers. In the next few decades, they will be called upon to meet and prevail over the ruthless challenge of the active and inventive minds behind the Iron Curtain. It must be realized that they are pioneers, who do not let past mistakes or precedents deter their advances or use of new ideas and practices.

As we enter the second hundred years of modern steelmaking, open-hearth operators and metallurgists can be counted on to continue the forward looking, excellent work they have done in years gone by and are doing today.

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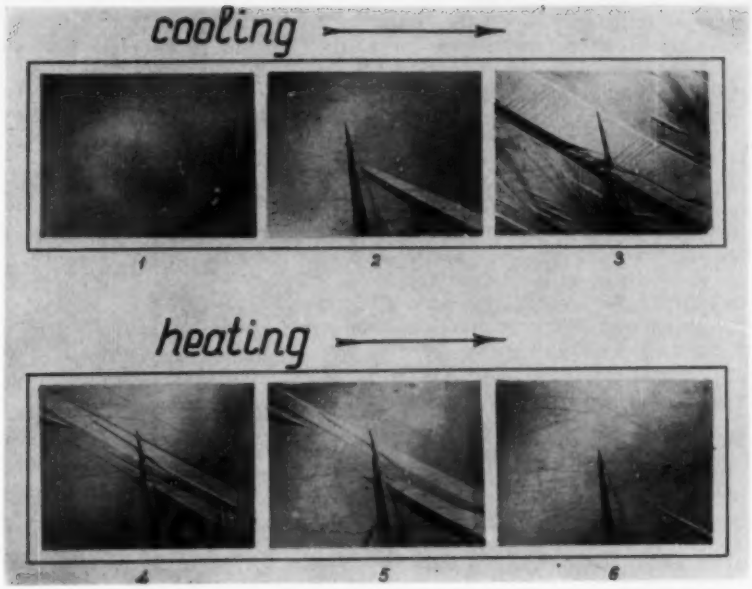

Fig. 1—Photomicrograph showing elastic martensite crystals.

THE NATURE OF MARTENSITIC TRANSFORMATIONS

The true nature of the martensite transformation was determined only in recent years. Presented here is a review of this work, given originally at the Second World Metallurgical Congress, by the noted Soviet Acamedician who is credited with this significant discovery.

by G. V. Kurdjumov

THE high rate of the austenite → martensite (A → M) transformation, the inability to prevent the transformation below the *Ms* point, the crystallographic mechanism of transformation, and numerous other facts brought out before 1940, led to the conclusion, at that time, that the transformation rate does not depend upon temperature, and that transformation rate is high at all temperatures.

Our investigations of phase transformations in copper alloys (1932 to 1940) have shown that A → M type transformations take place in supercooled β-solid soultions of copper-aluminum, copper-tin, and copper-zinc.[1] The high rate of transformation and its independence of temperature were explained by the following concept: "The mechanism of this type of transformation consists of a regular rearrangement of the lattice in such a way that the relative displacements of neighboring atoms do not exceed the interatomic distances and the atoms do not interchange places."[1, 2]

It was proposed to name all the transformations of the A → M type *martensite transformations.*

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Reversibility a key factor

The discovery of the *reversibility* of martensitic transformations in copper alloys—e.g. transformations having martensitic kinetics on cooling *and* heating[3, 4]—and the establishment of the reversibility in almost all known cases of martensitic transformations,[5] proved to be important factors in developing the concepts about the nature of martensitic transformations in general, and of the A → M transformation in particular.

This led to the interpretation of martensite in steel and of the martensitic phase in general as a low-temperature crystalline modification of solid solution, a modification which often exists only in a metastable state. It also became possible to consider the martensitic transformations as being similar to polymorphic transformations in pure metals.[6, 7] This, in turn, led to the concept of the metastable equilibrium between austenite and martensite with equilibrium temperature, T_0, depending upon the composition of the solid solution, and to the interpretation of this transformation as a process of nucleation and growth, governed by the general laws of phase transformations.[7]

Dependence of T_0 upon the concentration of carbon, and the concept of frozen composition fluctuations, were used by the author in 1941 as basis for the theory explaining the fact that A → M transformations take place over a range of temperatures.[7]

According to this theory, the martensite nuclei must form first of all in regions which are most depleted in carbon. The process of formation of martensite nuclei was considered on the basis of general thermodynamic theory about the nucleation of new phases. The high rate of growth was attributed to the low energy of activation due to the small relative displacements of atoms during the growth, and the absence of atomic exchange normally present in diffusion processes.

Further development of the new concepts had to wait until after World War II.

Post-war developments

Characteristics of the martensitic transformation were then surveyed in the light of the concept which interprets the transformation as a phase transformation proceeding through nucleation and growth in a one-component system.[8]

The peculiarities of martensitic transformations are as follows:

1.) The high rate of nucleation and growth in the temperature range in which all other processes are frozen—i.e., it is a diffusionless transformation;
2.) Termination of growth of the crystals of the new phase, although the original phase is still in existence and surrounding these crystals; and
3.) Termination of the process of nuclei formation when cooling (or heating) is stopped, although large quantities of the initial phase are still there

It was conjectured that low energy of activation for atomic displacements during the nucleation and growth of martensitic crystals is present only when the coherency between the lattices of the initial and the new phases is retained. The limited growth of crystals was attributed to the loss of coherency occurring when stresses at the boundary of the growing crystal reach a definite limit. These stresses rapidly increase with increasing size of the crystal, owing to the shear mechanism of atomic displacements and a preservation of coherency during the growth process.[9] Thus, we were interpreting the kinetic peculiarities of martensitic transformations from the point of view of general laws of phase transformations. There was no need to resort to the concept of the *athermal nature* of these processes in explaining the high rate of transformation. It was explained by the small magnitude of the energy barriers involved in these atomic displacements. All the peculiarities due to stresses were explained by the concept of coherent growth. Such notions about the nature of the martensitic transformations led to the logical conclusions, expressed by the author in 1947,[9] which presupposed the possibility of two new phenomena:

1.) A low rate of martensitic transformation at sufficiently low temperatures; and
2.) A thermoelastic equilibrium between original and martensitic phases and *elastic* martensitic crystals which increase in size with decreasing temperature, and vice versa.

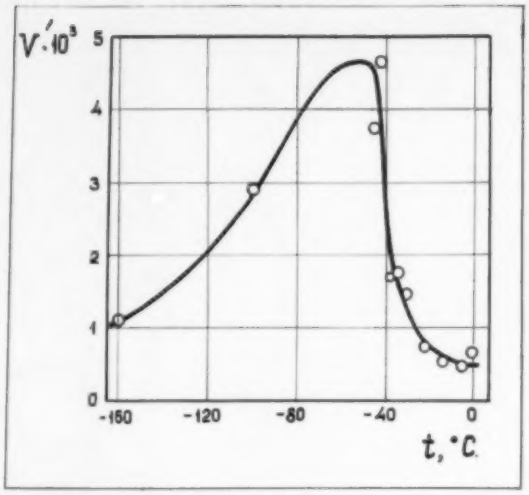

Fig. 2—Temperature dependence of transformation rate.

These conclusions contradicted all that was known before about martensitic transformations, but both predicted phenomena were actually observed in our experiments of 1948.[10,11]

Thermoelastic equilibrium

The second supposition (above) was based on the following considerations: great elastic energy should arise during the coherent growth of a martensite crystal; at certain conditions this positive part of the free energy change may increase more rapidly during crystal growth than the negative part—the free energy difference between the new and original lattices. Thus, the total free energy may pass through a minimum when the dimensions of the martensite crystal increase. If this happened before the disruption of coherence, the growth would stop, and the martensite crystal would be in thermoelastic equilibrium with the original phase. A raising of the temperature would then lead to the shrinking of the crystal but lowering of temperature would lead to its growth.[8]

The possibility of such a behavior of martensite crystals was indeed found in the $\beta_1 \rightleftharpoons \gamma'$ transformation in copper-aluminum alloys containing some manganese or nickel.[11] Fig. 1 shows some *elastic* martensite crystals.

Thermal characteristics

Work announced in 1947 established that at temperatures below −50°C the A → M transformation has the following basic thermal characteristics:[9] a) the transformation proceeds with a measurable rate, decreasing with decreasing temperature; b) at sufficiently low temperatures, −180° to −195°C, the rate of transformation becomes practically zero; and c) in some steels, the A → M transformation may be prevented by rapid cooling to liquid nitrogen temperatures. Further transformation will begin on heating the supercooled austenite above the temperatures of liquid nitrogen and will proceed at a rate which increases with increasing temperature.

Microstructural investigation has shown that the transformation rate in steels and iron-nickel alloys

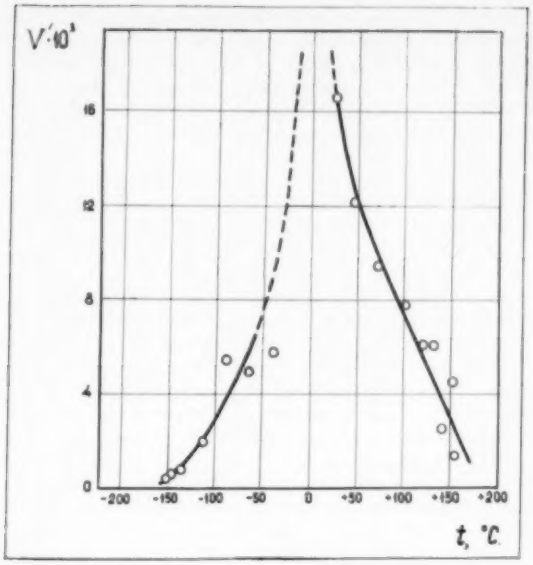

Fig. 3—Temperature dependence of transformation rate, for 0.85 pct C, 2.2 pct Mn steel (Ms = 155°C).

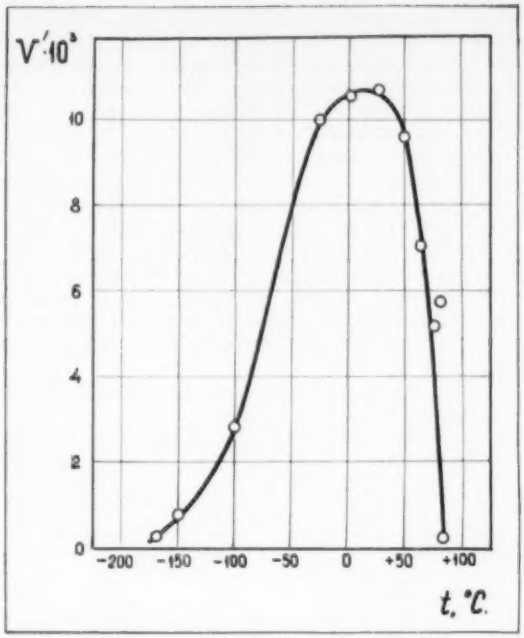

Fig. 4—Temperature dependence of transformation rate, for 0.954 pct C, 3.5 pct Mn steel (Ms = 85°C).

is controlled by the rate of nucleation, since the growth of each small crystal is limited, and proceeds rapidly within the entire temperature range.[12]

The decrease in the rate of nucleation with decreasing temperature, and the complete termination of the process at sufficiently low temperatures, shows that for the progress of the A → M transformation, and above all for its nucleation, there is need for a definite energy of thermal vibrations. Consequently, one of the basic factors which determines the kinetics of the martensitic transformations is the thermal motion, and, in this respect, it does not differ in principle from any other phase transformation in alloys. The difference here is that the martensitic transformation takes place at much lower kT values, and, therefore, freezing takes place at much lower temperatures than the usual type of phase transformation.

Subsequent studies have demonstrated that temperature dependence of the transformation rate may be of the same form as that which is common for all phase transformations i.e., as the temperature decreases the rate of transformation increases initially, reaches a maximum, and then decreases, as shown in Fig. 2. This was first shown on the alloy Fe—23 pct Ni—3.4 pct Mn.[18]

In the temperature range which lies below the temperature corresponding to the transformation rate maximum, the factor which limits the rate of nucleus formation is the small energy of thermal vibrations. In the temperature range above the transformation rate maximum, such a limiting factor is the large free energy change involved in formation of nuclei of critical size.

The magnitude of this change increases rapidly with a decrease in the degree of supercooling. This means that thermal fluctuations necessary for formation of embryos of critical size play a leading role in the progress of transformation in the temperature range above the transformation rate maximum.

It has long been known that, in steels, the transformation proceeds isothermally for some time when cooling is interrupted between the *Ms* point and room temperature.[14-20] However, its nature remained vague, for the phenomenon itself contradicted the notions about the nature of this transformation. Because of this, it was usually linked with secondary diffusion processes.

In order to understand the nature of this phenomenon, the temperature dependence of the rate of isothermal A → M transformation was determined for a steel containing 0.85 pct C and 2.2 pct Mn, with the *Ms* being about 155°C. It turned out that the initial rate of isothermal transformation first increases with decreasing temperature, Fig. 3, then exhibits exceedingly high values in the +25° to −50°C range, and finally decreases rapidly below −50°C.[21]

Conditions for nuclei formation

This investigation has demonstrated that the high rate of martensitic transformation within the temperature range close to room temperature is due to the fact that the temperature range involved is so far below the point T_0, (the temperature at which free energy of A and M are equal) that the work of nuclei formation becomes insignificant, but the energy of thermal vibrations is still sufficiently high. This results in formation of all of the nuclei of critical size which are capable of forming at the given temperature, immediately on reaching this temperature. This is the reason why the isothermal transformation is not observed in this temperature range. The transformation acquires a seemingly *athermal* nature. But it is possible to slow down the rate of transformation in this temperature range, provided the free energy of formation of nuclei is increased.

The rate of martensitic transformation near room temperature can be decreased only when the equilibrium point I_0 is decreased by changing the austenite composition. Experiments carried out on steel containing 0.954 pct C and 3.5 pct Mn (*Ms* = 85°C) confirmed this conclusion.[21] The rate

of isothermal transformation was measured for this steel over the entire temperature range. The temperature dependence curve of the initial rate of isothermal transformation had the form usually found in phase transformations, with the maximum at 25°C, as shown in Fig. 4.

It should be noted that the authors did not succeed in supercooling all of the austenite of the investigated steels to the temperatures at which the isothermal transformations were studied. There is no doubt that the presence of the martensite forming during the cooling, prior to the beginning of the isothermal process, distorts the rate vs temperature curve, but does not alter its meaning in principle. The curve correctly depicts the nature of the kinetics.

It is easiest to obtain a complete set of data for the dependence of the transformation rate on temperature in the iron-nickel-manganese alloys mentioned above.[10] Philbert and Crussard obtained similar data for steel containing 1.4 pct C, and 2.5 pct Cr, with a maximum rate at −20°C.[22] The same work established the presence of an incubation period, also found by Shih, Averbach, and Cohen,[23] where is was shown that complete suppression of transformation on cooling to the isothermal holding temperature is necessary to observe an incubation period. The experimental data concerning the transformation of austenite to martensite which we obtained[10,12,13,21,24,25] were in general confirmed by a number of other investigators[22,23,26–32] and theoretically considered in a number of papers.[33–37]

Effect of deformation

In one of the investigations, we found that plastic deformation of austenite leads to a significant change in the rate of isothermal transformation and causes a displacement of the temperature of the transformation rate maximum; however, plastic deformation does not change the general form of temperature dependence of the transformation rate.[27]

The effects of plastic deformation, prior phase transformations, and neutron irradiation have been studied at our Institute on a number of steels and alloys.[40–44]

These investigations lead to the conclusion that, as a result of the above mentioned interactions, two kinds of structural changes,—imperfections of crystal structure—take place in austenite. These structural changes can be distinguished by their effect on the transformation. Changes of the first kind stimulate the transformation by raising the *Ms* point, increasing the total amount of martensite which is formed on cooling, and increasing the rate of isothermal transformation. Changes of the second kind have an opposite effect. Structural imperfections of the first type are unstable and, for iron-chromium-nickel alloys, disappear in the temperature range of 100° to 400°C.[45] The process of disappearance proceeds slowly, even at room temperatures.[46] Structural irregularities of the second type disappear for the same alloys only after tempering above 400° to 500°C.

Both types of structural imperfections will be present when plastic deformation is used to introduce them. However, the effects of structural changes of the first kind will prevail in the case of small plastic strains or neutron irradiation. If the degree of plastic deformation increases, a point will be reached where the effects of the two kinds of defects will cancel each other. With further increase of plastic deformation, the effects due to the second kind of imperfection will prevail, and a slowing down of the transformation will be observed, Fig. 5a.[45] The stimulating effect of plastic deformation will be more pronounced for alloys with a high yield point, such as iron-nickel-carbon or iron-nickel-chromium. For iron-nickel-manganese alloys, which have a low yield point, only the retardation effect is observed, Fig. 5b. However, since the retardation effect in these alloys is increased as the result of room temperature aging, Fig. 6, or tempering at 100° to 200°C, one is led to believe that structural imperfections which stimulate transformation are also present.

It is probable that both kinds of structural imperfections also arise in untransformed austenite, as a result of formation of martensite crystals. The disappearing of imperfections of the first kind during the interruption of cooling and the preservation of imperfections of the second kind must then be the cause of the well-known austenite stabilization.

We cannot consider here the nature of both of these types of imperfections, but some opinions have been published.[45]

Conclusions

Experimental data on the kinetics of transformation and the role of various effects on the kinetics of transformation lead to the conclusion that a definite thermal energy of atomic vibrations is

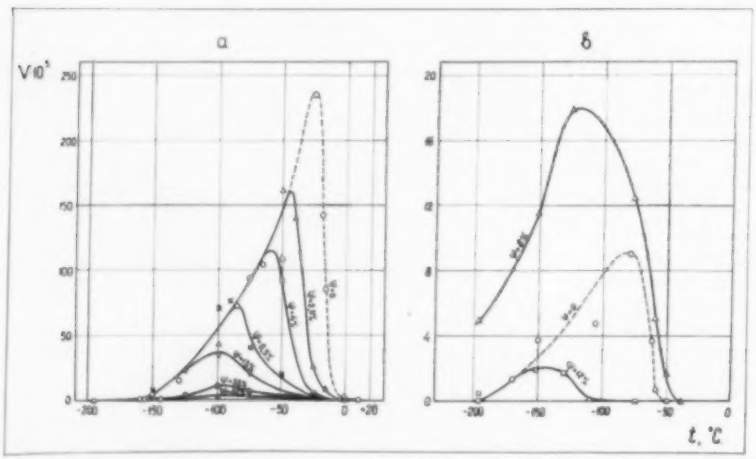

Fig. 5a—Displacement of transformation rate curve due to plastic deformation.
Fig. 5b—Retardation effect observed in Fe-Ni-Mn alloys.

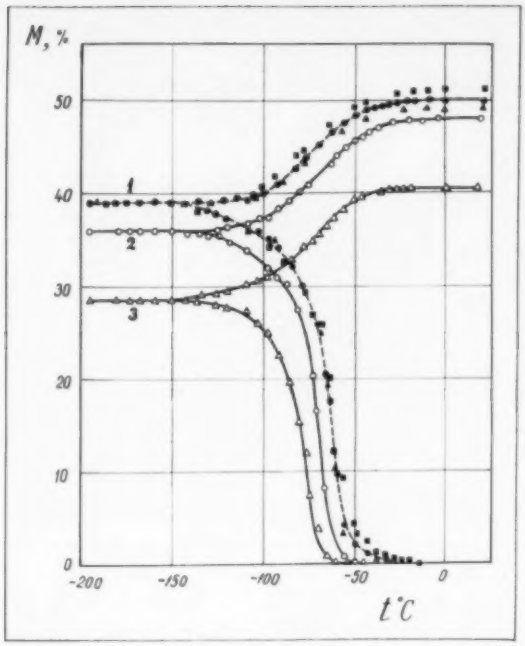

Fig. 6—Increase of retardation effect due to room temperature aging.

necessary for the formation of a martensite nucleus of critical size. The magnitude of this energy is not large, since it is known that a very high rate of nucleation already exists at temperatures from −50° to 0°C. In those cases when the nucleus cannot form in this temperature range because of thermodynamical reasons (high work of nuclei formation), the transformation may be suppressed by rapid quenching to liquid nitrogen temperature.

The rate of growth of the martensite crystals, which one observes under the microscope, is extremely high. This is apparently due to the stresses which are created in the process of growth. These stresses accelerate further growth by lowering the barriers for atomic displacements. Then the great rate of growth of crystals becomes possible even at very low atomic vibration energy. The experiments show that atomic vibration energy at liquid nitrogen temperature is not large enough to overcome barriers during the growth of martensite nuclei up to critical size and apparently on into the first stages of growth of martensite crystals. Otherwise it would not be possible to freeze the transformation by immersion in liquid nitrogen and to stimulate it by subsequent raising of temperature. The rate of martensite transformation will then depend upon the atomic vibration energy even in such cases as when nuclei of critical size are already present and no thermal fluctuations are required for their formation. The rate will depend upon temperature; it will decrease with lowering of temperature and become extremely small at sufficiently low temperatures.

All this shows that the austenite → martensite transformation, and martensitic transformations in general, are basically thermal phenomena, just as all other phase transformations. As in other transformations, the rate of formation of martensite nuclei is governed by the change of free energy and by the kinetic energy of atoms.

The *athermal* formation of embryos is, in reality, a thermal process, which takes place at an extremely high rate. It is well known that a number of diffusion processes cannot be suppressed by rapid cooling, even if they are taking place at a high temperature. For example, in many cases it is impossible to suppress the ordering process or precipitation processes. However, no one tries to talk about the *athermal* nature of these processes. The martensitic transformation is distinguished by the fact that it does not require diffusion of atoms. However, the kinetic energy of atomic vibrations is required, although it is of a considerably lower order of magnitude. This only leads to a lowering of the temperature at which the process may be frozen.

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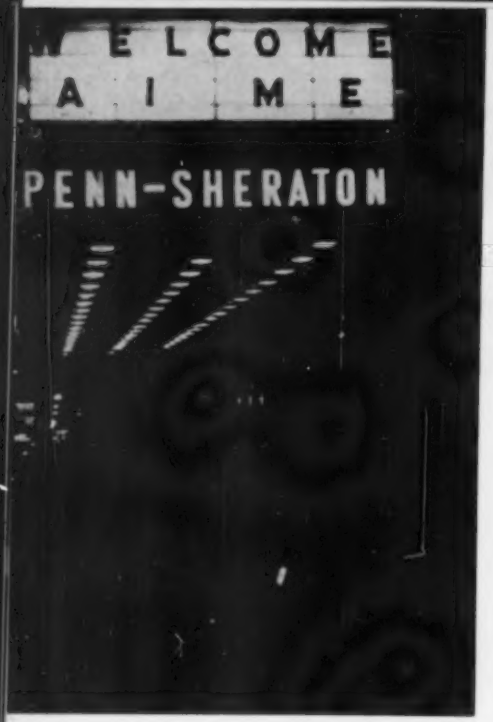

International Symposium on PHYSICAL CHEMISTRY OF PROCESS METALLURGY

by George R. St. Pierre

During the last week of April process metallurgists from the US and 11 other countries assembled in Pittsburgh to exchange ideas and present recent research on the physical chemistry of process metallurgy.

FOR the last few years, process metallurgists throughout the world had been anxious to assemble for the purpose of exchanging ideas and presenting recent research on the physical chemistry of process metallurgy. Eleven years had elapsed since the Faraday Society sponsored the last international symposium. About a year ago, Professor John Chipman and several friends decided that another symposium should be held in America during the spring of 1959. Professor C. Law McCabe of Carnegie Institute of Technology and Professor John F. Elliott of Massachusetts Institute of Technology accepted the responsibility of arranging the meeting. The Pittsburgh Section of the AIME graciously agreed to act as host, and General Chairman Law McCabe established the Symposium dates of April 27 through May 1, 1959 with the Penn-Sheraton Hotel as headquarters.

The interest in the meeting was even greater than had been anticipated. All three divisions of The Metallurgical Society contributed to the plans. Many papers from overseas metallurgists were received, and the final registration showed that 11 countries were represented at the meeting.

Twelve technical sessions

John Elliott and Law McCabe put together, after much consideration, a program covering four days of technical sessions and a day of visits to research laboratories in the Pittsburgh area. The program consisted of 12 sessions, each of which brought together several papers related to an important topic. One of the most significant features of the program was the complete absence of the separation of papers between ferrous and nonferrous activities.

The titles of the various sessions were: Physical Chemistry of Metallurgical Phases, Physical Chemistry of Oxide Phases, Thermodynamics of Metals, The Nature and Structure of Liquid Metals, Transport and Mixing, Solubility and Phase Equilibria in Metal Systems, Process Reaction Rates and Mechanisms, Solidification of Metals, Halides, Carbides, and Sulfides, Industrial Applications, Hydro- and Electro-Metallurgy, and Process Control and Statistical Methods. Another important feature was the large number of papers related to kinetic and structural properties of metallurgical melts. Although there were several outstanding papers presenting industrial application, everyone hoped for an increased effort in this direction.

In the mornings a single session was held which was of general interest to the whole gathering, while in the afternoon it was necessary for each attendant to select one of two competing sessions. This often was the toughest decision of the day. In addition to these well-conceived technical sessions, two evening gatherings were planned. Of course the formal gatherings were supplemented by many small informal discussion groups which formed among the 375 registrants. Many friendships were renewed with the 24 participating overseas metallurgists.

This report cannot cover all of the significant work which was presented at the meeting. Fortunately, The Metallurgical Society and Interscience Press will publish the Proceedings of the Symposium, with Dr. George R. St. Pierre acting as Editor. In the discussion to follow, an attempt is made to convey the character of the meeting and not to present a detailed report. Many fine contributions will not be mentioned.

Professor Richardson of the Imperial College, London, gave the opening lecture, *The Solutions of the Metallurgist—Retrospect and Prospect.* After tracing the historical development of the present state of knowledge on liquid metal and slag solu-

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An informal discussion between John Chipman, F. D. Richardson of The Imperial College, and Georges Urbain of IRSID.

tions, Dr. Richardson discussed the various methods by which the thermodynamic properties of solutions can be derived. Although none of the present models gives satisfactory results in all cases, he showed the usefulness of the quasi-chemical treatment. Dr. Richardson emphasized the need for a great deal of additional, well-organized data on the thermodynamic properties of metallurgical solutions. An array of such data is useful not only to the practicing process metallurgist, but it would also serve as an invaluable guide to the theoretician attempting to reveal the underlying behavior.

Later in the morning, Professor John Chipman delivered a special lecture on the *Thermodynamic Properties of Iron-Blast-Furnace Slags.* After outlining the progress of his research on blast-furnace slags which began shortly after the World War II, he discussed in detail the differences which exist in the reported values of the activities of lime and silica in blast-furnace slags. Dr. Chipman presented additional support for the values obtained in his own laboratory. He described a new method of analyzing sulfur equilibria involving slags in terms of the component SO_{-1}, which, although puzzling at first, provides a simplified approach to such systems.

The application of statistical mechanics and irreversible thermodynamics to problems of process metallurgy drew considerable interest. The featured lecture by Professor Henry Eyring of the University of Utah, *Modern Concepts of Metallurgical Systems and Processes*, established high goals for researchers in process metallurgy. He illustrated the use of statistical mechanics to determine the thermodynamic properties of metals from rather simple measurements.

The Symposium Officers: John F. Elliott, Technical Chairman; C. Law McCabe, General Chairman; and George R. St. Pierre, Editor of The Proceedings.

Professors S. Takeuchi and K. Furukawa of Tohoku University, Sendai, Japan presented *Statistico-Thermodynamical Studies on the Fe-O System in the Molten State,* which established from a rather simple model the properties of the Fe-O system. In an outstanding paper, *A Study of the Solidification Process in Chill-Cast Al-Cu Ingots,* Professor Kirkaldy of McMasters University, Canada, applied the principles of irreversible thermodynamics to the explanation of the morphology of cast metals. He demonstrated that the thermodynamic requirement that the system pass through states of minimum or decreased entropy production rate can lead to typical cast structures. An interesting discussion of this paper by Dr. Tiller will appear in the Proceedings. Kirkaldy's analysis points the way for additional application of irreversible thermodynamics to metallurgical systems.

The extension of the temperature range of metallurgical studies was illustrated by the research presented by Dr. P. Kozakevitch of IRSID (the French Steel Research Institute), *Viscosity of Lime-Alumina-Silica Melts Between 1600° and 2100°C.*

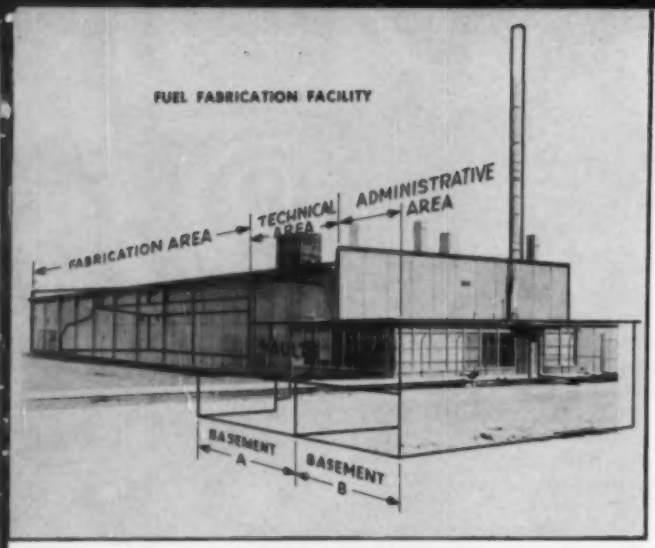
The paper of B. M. Larsen and L. O. Sordahl, *Some Mechanisms in the Refining of Steels,* reported the results of a detailed and very careful study of a laboratory model open hearth. The conclusion that the rate of carbon removal was controlled by the diffusion of oxygen through a gas boundary layer at the slag interface is certainly of great significance.

There was active discussion during all of the sessions. The availability of preprints before the start of the meeting added greatly to the participation. The discussions will be included in the Symposium Proceedings.

Banquet and final session

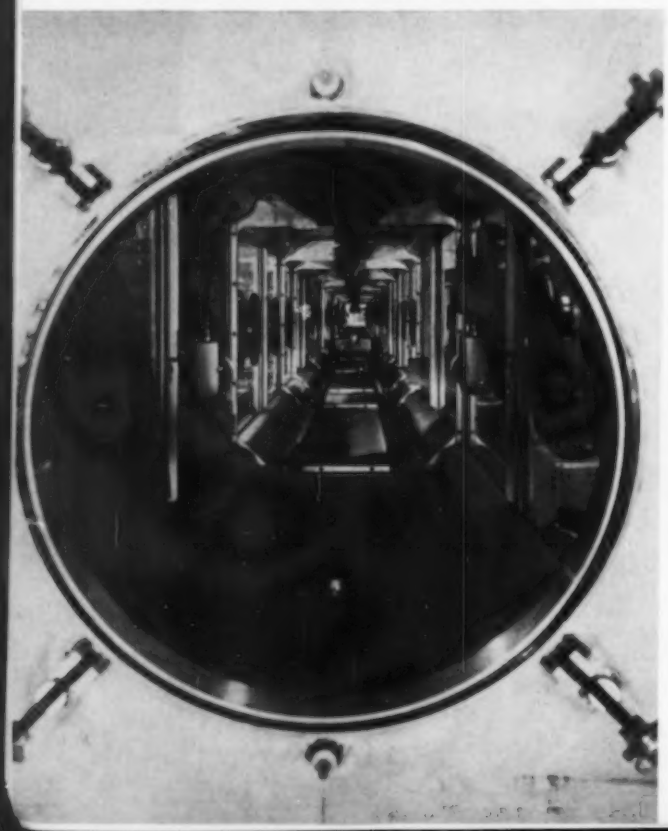
On Monday evening, a banquet was held in the Terrace Room of the Penn-Sheraton Hotel. Dean G. R. Fitterer of the University of Pittsburgh welcomed the out-of-town Americans and overseas visitors. Dr. J. B. Austin, Administrative Vice President for Research and Technology, U. S. Steel Corp., gave an address entitled, *Public Relations for Science—A Problem in Communications.*

The final session of the symposium included a challenging talk by Mr. Cuthbert Daniel, engineering statistician of New York, *Statistical Design of Experiments in Process Metallurgy.* At the conclusion of the formal presentations a number of people were called upon to discuss various aspects of the meeting and to speculate a bit on the future activities of the field. The increasing need to draw heavily upon the talents of mathematicians, physicists, and chemists was emphasized. The growth of industrial groups formed for the purpose of applying physical chemical principles to metallurgical processes was highly praised. There was a strong feeling that 11 years is too long to wait for the next international symposium on the physical chemisty of process metallurgy.



Known as the Fuel Fabrication Facility, this building and its intricate equipment are the culmination of more than three years of design work, two years of construction, and $4 million. The above view shows the three air-lock connected areas in the building.

Below—This conveyor line, shown from the east end, connects the various working areas in the new building. Just inside the entrance are photoelectric light cells which comprise part of the conveyor interlock safety system.



ARGONNE OPENS

ARGONNE National Laboratory recently opened its new $4 million fuel fabrication facility designed for developmental research on fabrication of plutonium fuel elements. The new laboratory is to be part of Argonne's Fuels Technology Center now under construction.

Plutonium offers many advantages for economic nuclear power production, explains Dr. Frank G. Foote, director of Argonne's metallurgy division. Speaking at the opening of the new lab, he said, "Simply from the standpoint of being able to manufacture fuel for reactors instead of remaining dependent on supplies of natural uranium scattered throughout the world, intensive research on plutonium seems to be justified." "But", he continued, "plutonium recommends itself in still another way. Early in the development program, reactor engineers became aware that of the three fissionable isotopes available to us, plutonium has the most favorable nuclear characteristics in a fast reactor in which no moderating material is used to slow down neutrons, as is done in a thermal reactor. Such a reactor fueled with plutonium and blanketed with a layer of natural uranium will not only produce power but will also breed more plutonium in the blanket than is consumed as fuel in the core."

However, together with these advantages, one must consider the fact that plutonium is perhaps the most dangerous to handle of the three fissionable elements. In addition to its ability to achieve criticality and constitute a radiation hazard, plutonium is a very strong alpha particle emitter, and, in some forms, is pyrophoric. While a thin film of plastic, foil, or skin will stop alpha particles, they can do extreme damage if the emitter is inhaled or in any way ingested. The National Committee for Radiation Protection has set 0.13 μg (13 hundred millionths of a gram) as the maximum permissible limit of insoluble plutonium in the human body.

The above considerations go a long way toward explaining why a plutonium handling facility is so expensive. Portions of the building where radioactivity may be present are completely sealed to the outside. The three working areas of the building —administrative, technical, and fabrication—are sealed from each other, access between areas permitted by means of air locks. The technical area is kept at slightly less than atmospheric pressure and the fabrication area, where radioactive dust is most likely to originate, is at still lower pressure.

Equipment in the fabrication area ranges from a few pounds to nearly 50 tons in weight, and is located in a system of interconnected gas-tight enclosures. This system of enclosures is 140 ft long and 60 ft wide—glove boxes on a truly colossal scale! The atmosphere inside the enclosures is helium, pressurized lower than the surrounding room so that leakage is *into* the system instead of *out* of it. Helium was chosen because of its high

PLUTONIUM FACILTY

heat capacity and excellent heat transfer characteristics, amenability to purification, and the ease with which highly sensitive methods determine leaks. Leakage of air into the system is estimated at only 0.02 pct per hr.

Equipment of standard design was used because it was readily adaptable to glove box enclosure and operation. However, it was found that most of the machines required some modification for gas-tight housing or for parts requiring maintenance.

Machines are all placed so that they adjoin the central conveyor system, which runs the length of the fabrication section. Transfer from the conveyor to the machines is by means of two-way slide transfer platforms through sealing doors. Equipment is divided among the several manufacturing phases.

Machine shop: Equipment in this section includes a 50-ton hydraulic press of special design, a 10-in. toolmaker's lathe, a vertical milling and boring machine, sheet metal shear, universal milling tool grinder, and a milling machine.

Weighing and inspection: Here are included several analytic balances, a hardness tester, dial comparator, and enough space for other equipment that might be needed.

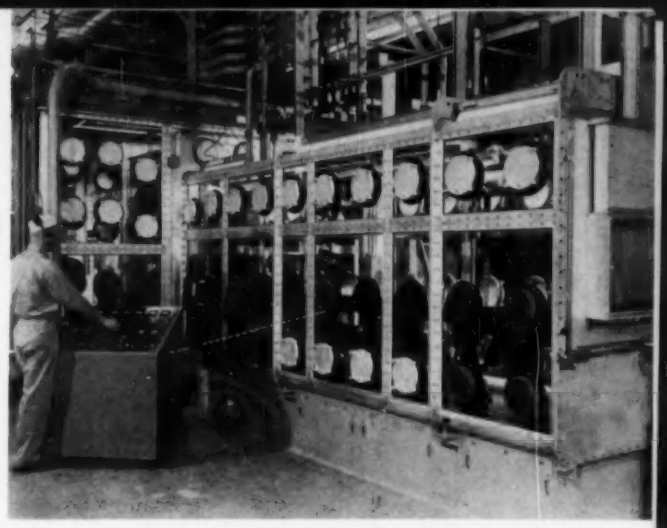
Casting lines: Casting facilities include two centrifugal casting machines, an ingot casting machine, and a gas pressure injection casting machine. All of the equipment can be operated in a vacuum of less than 0.0001 mm Hg, achieved by a diffusion pumping system. Associated furnaces have 10 kg capacity.

Extrusion press: A specially designed 600-ton extrusion press is currently being built, and is expected to be installed later this year.

Rolling mill: A two-high, four-high rolling mill has been installed which has 10 x 14 in. two-high work rolls . . . four-high backing rolls . . . and 2½ x 14 in. four-high work rolls. Feed and tensioning equipment, mill drive, and billet manipulators are all in the enclosed line. Also included is a high vacuum rod annealing furnace equipped to anneal billets at 1200°C in a vacuum of 0.0001 mm Hg.

Other equipment—all enclosed in hoods and operated from outside—includes a ½ in. x 6 ft. capacity plate shear . . . swaging machines . . . a hydraulic draw bench . . . a smaller rolling mill . . . a specially designed 250-ton press for powder working, welding and jacketing facilities with a rotary positioner . . . a liquid metal bonding line . . . and other auxiliary equipment.

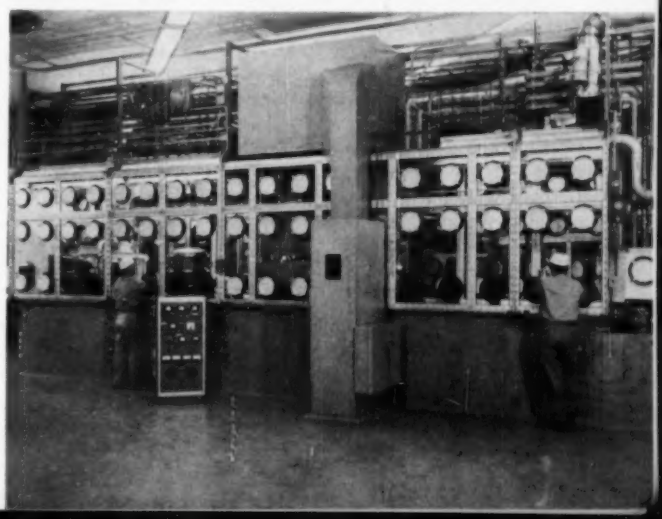
At the opening ceremonies, Dr. Norman Hilberry, Director of the Argonne National Laboratory, commented: "With the Fuel Fabrication Facility available, and the Fuels Technology Center moving steadily toward completion, we are entering a new era in plutonium research. The net result should be a gratifying expansion of our basic knowledge of this tricky, hazardous, element and a significant increase in our ability to make it our servant."



Above—Rolling mill area, which can be operated from two separate remote control panels.

Above—Overhead view of the fuel fabrication area, looking toward the entrance. Hood lines visible include two casting lines, weighing and inspection, machine shop, and liquid metal; at right is the central conveyor.

Below—Operators working at the pressing and powder metal working line.



PREDICTING MINIMUM MATERIALS COST FOR STAINLESS STEELS

A linear programming model of Type 430 stainless steel melting process has been devised from the technical and practical factors involved. Although further refinement of the model is presumably desirable to make it applicable to specific shops and furnaces, the technique appears to have great potential as a guide to the design of the most economical practice for using available materials in the production of stainless steel.

by D. C. Hilty, R. W. Taylor, and R. H. Gillespie

Editor's Note: While the general principles which this paper outlines are scientifically valid, it is important to emphasize that the specific results are based on an average practice and on the price economics in effect in October 1958. Changes in the prices of materials involved could, of course, materially change the final results.

OVER the past 30 years, production of stainless steels in the US has increased until they have become a significant item of tonnage in the total annual ingot output and a major economic factor. Much of the growth during the last 10 years has been assisted by economic and technological advances stemming from the use of gaseous oxygen for decarburizing the bath and from improvements in arc furnace design and operation. Projection of the growth curve into the future suggests that stainless steel production may double in the next 10 years. Continued rapid growth is, of course, dependent to an important degree upon achieving and maintaining the lowest possible production costs consistent with product quality.

As a supplier of raw materials, especially chromium, to the stainless steel industry, Union Carbide Metals Co. obviously has a major interest in the further development of stainless steel production. Consequently, a little over 10 years ago we began a large-scale study of the chemistry of stainless steel melting in order to gain a thorough understanding of the process. Such an understanding was considered essential to the design and manufacture of ferrochromium alloys that would be best suited to both the technical and economic requirements of the steelmaker in the future. In addition, the information derived from such a study would be of great value to the steelmaker as a guide in using most effectively the materials and facilities available to him.

Results of this program have been published over the past 10 years. The first paper, defining the relationship of chromium and carbon to temperature in a molten steel bath,[1] provided the fundamental basis for studies of the oxidizing and reducing periods and control of quality factors of stainless steel heats that followed.[2, 3, 4, 5, 6, 7, 8, 9, 10, 11] The data gathering and evaluating phase of the program by conventional experimental and analytical methods came to a conclusion in 1957 with the publication by Healy and Hilty of an engineering analysis of the effect of oxygen-blowing rates.[10] This paper illustrated how the fundamental relations that have been evolved may be utilized for control of the melting operation.

D. C. HILTY, R. W. TAYLOR, and R. H. GILLESPIE are with the Metals Research Laboratories, Union Carbide Metals Co., div. of Union Carbide Corp., Niagara Falls, N. Y. This paper was presented at the 1958 AIME Electric Furnace Conference in Detroit.

Nature of the problem

In spite of the fairly detailed technical understanding of the process previously developed, our initial efforts to employ this information for better appraisal of the economics of stainless steel melting with regard to raw materials met with indifferent success. Clearly, technological advances have given the steelmaker great flexibility in the matter of using available materials, the full potential of which has probably not yet been realized. Perusal of the AIME *Electric Furnace Steel Proceedings* for the past few years, however, will quickly demonstrate that attempts to utilize this flexibility to obtain increased operating economies based on materials have frequently produced inconsistent and sometimes contradictory results. Further study convinced us that, although the essential data might be at hand, the complexity of the problem was such that conventional methods of correlating the information were inadequate except on an intuitive trial and error basis.

Reduced to its simplest essentials with respect to materials use, a stainless steel heat can be considered to involve four major operations: 1) charging and melting, 2) oxidation, 3) slag reduction, and 4) finishing. All of these operations are interrelated so that almost anything happening in one of them is accompanied by a compensating effect in each of the others.

Although chromium is a common denominator in these stages, complications are introduced because four major classes of chromium-bearing materials are normally available: 1) chromium-bearing steel scrap, 2) high-carbon ferrochromium, 3) ferrochromium-silicon, and 4) low-carbon ferrochromium. While each of these classes of materials is technically suitable for addition at one or more of the stages of the heat, the amounts that can be added economically depend on the collateral influences they exert on the other stages and on various practical operating considerations.

Similar sets of conditions control the use of the other classes of materials. When one also considers

the numerous specific alloys of different compositions and prices that constitute these classes, to say nothing of the other materials, such as steel scrap, lime, and oxygen, that contribute to the cost of stainless steel, the complexity of the situation becomes unmistakable.

Further study led to the conviction that the problem was essentially mathematical in nature. In fact, a formal mathematical approach, supplemented by the availability of a digital computer for carrying out the calculations, offered the only practical means of relating so many interacting variables at the same time. Moreover, the mathematical techniques of linear programming appeared especially appropriate for the job, because most of the relations in stainless steel melting could be expressed as linear relations without introducing serious error.

Linear programming

Linear programming is a mathematical procedure, algebraic in nature, that has been developed in recent years for solving complex problems of optimization; i.e. problems involving combination of a number of interacting factors to produce a maximum or minimum result. Basically, linear programming is suitable for application to any such problem if the following three criteria can be met:

1) There is some function, such as profit, cost, power use, yield of product, calories in a diet, or time, that must be made a maximum or minimum;
2) There is a variety of solutions, each subject to a set of well-defined restrictions that can be expressed as equations or inequalities, and;
3) Among the many variables of the problem, the relation between any two can be represented by a straight-line plot or equation, at least to an acceptable degree of approximation.

To date, most of the publicized applications of linear programming have been in the field of business planning and operation. In this area, the technique is no stranger to the steel industry. For example, Truan and Porco[12] have described the use of linear programming in the long-range planning of coke oven replacements.

Lately, however, interest in employing linear programming for control of technical processes has been developing in practically all fields of science and technology, especially those of the chemical and related industries.[13, 14, 15] An excellent example of this interest, in regard to iron and steel production, can be found in a recent paper by Fabian.[16] Fabian proposed the use of linear programming to determine the least cost rate of input of materials in an integrated steel mill. He presented mathematical formulations (models) of the various stages of iron and steel production based on technology. The individual mathematical models were then connected to form a *master model* simulating the integrated operation. Although Fabian's treatment of the problem was hypothetical and possibly oversimplified in that no specific data were used, it clearly illustrates the potential of the method. In many respects the procedure used by the present authors is similar to that suggested by Fabian.

Mathematically, a problem amenable to linear programming normally consists of a set of simultaneous linear equations with more variables than there are equations. The solution is obtained by finding the combination of variables, equal in number to the number of equations, that will give a minimum (or maximum) answer in the case of the function being optimized. Such a solution can be obtained manually by trial and error simply by selecting a set of variables, solving the equations simultaneously by conventional algebraic methods, and then repeating the process until all possible combinations of the variables have been tested. In most instances, however, this procedure is so tedious and time-consuming as to be impossible for all practical purposes. Consequently, the so-called linear programming techniques have been developed for solving such optimization problems rapidly and accurately. Several of these computational procedures have been evolved.[17] The one employed for our work was the *Simplex* method of linear programming described by Charnes, Cooper, and Henderson.[18]

A Datatron 205 electronic computer was utilized for the actual numerical results that are reported.

Model for Type 430 stainless steel

Type 430 was selected as the grade of stainless steel to be studied because it provided greater technical simplicity for this initial demonstration of the technique. Moreover, it represents a major fraction of the stainless steel tonnage produced. In addition, the model, as developed below, can be readily modified to include other members of the 400 series and can be expanded without undue effort to include the 300 series.

Steel scrap, Type 430 scrap, and some type of high-carbon ferrochromium are charged into the furnace and melted down. It is assumed that during this melt-down period any silicon present, up to 0.50 pct of the charge, will be oxidized by air, or by scale, rust, etc., present in the charged materials. The resulting silica will dissolve an equal weight of magnesia from the furnace lining.

Oxygen is then injected to bring the carbon content down to approximately 0.05 pct, after first oxidizing any residual silicon. At this time, there is unavoidable oxidation of metal.

Immediately after the oxidation period, silicon-bearing alloys are added to reduce the metallic values from the slag to the greatest extent practicable. Lime is added to adjust the basicity of the slag, and clean Type 430 scrap may be added for its cooling effect. In addition, low-carbon ferrochromium alloys may be added at this point. Power may be necessary to maintain fluidity of the slag and control bath temperature.

This reduced slag is then removed, and a finishing slag is formed by the addition of ferrosilicon and lime. Final additions of low-carbon ferrochromium alloys may now be necessary to bring the final composition to the desired level.

The various technological and practical aspects of stainless steel melting have been combined into a set of 11 linear equations and inequalities, along with a cost function which is to be minimized. The composition used in this study is typical of Type 430: 16.5 pct Cr, 0.40 pct Si, and max 0.08 pct C. All equations are presented on the basis of the production of one net ton of liquid Type 430, just prior to tapping. An explanation of each of the equations and inequalities follows, beginning at the finish of the heat and working backward toward the charging period.

$$\begin{bmatrix}\text{One Net Ton}\\ \text{of Type 430}\end{bmatrix} = \begin{bmatrix}\text{Sum of Metallics}\\ \text{Charged}\end{bmatrix} + \begin{bmatrix}\text{Si + C in}\\ \text{Final Metal}\end{bmatrix} - \begin{bmatrix}\text{Metallics in}\\ \text{First Slag}\end{bmatrix} \quad [1]$$

This first equation is merely a metallics balance. It states that the metallics charged during the heat appear either as liquid Type 430 ready for tapping or else in the first slag. The silicon and carbon specifications of 0.4 and 0.08 pct, respectively, are met. It should be stressed again that the metallics involved are iron, chromium, and manganese; since Type 430 is under consideration, no nickel is included. For a large furnace, the first slag will contain about 10 pct metallics at 1.5 basicity, from Fig. 2, based on reference 5.

$$\begin{bmatrix}\text{Si Added}\\ \text{After } O_2\\ \text{Blow}\end{bmatrix} = \begin{bmatrix}\text{Si Equivalent}\\ \text{to } O_2 \text{ for}\\ \text{Metallic Oxidation}\end{bmatrix} + \begin{bmatrix}\text{Si in}\\ \text{Final Metal}\end{bmatrix} - \begin{bmatrix}\text{Si Equivalent}\\ \text{to Metallics}\\ \text{in First Slag}\end{bmatrix} \quad [2]$$

Eq. 2, which describes the silicon required for reduction, is similar in form to Eq. 1. The silicon supplied after oxidation can come from various sources: ferrosilicons, ferrochromium-silicons, 430 scrap added primarily for cooling, and from any of the low-carbon ferrochromiums added during this period. It is equal to the stoichiometric amount of silicon needed to reduce all the metallic oxides from the slag (chromium, iron, and manganese), expressed in terms of the oxygen consumed for metallic oxidation, plus the silicon specification of the final metal, less the silicon equivalent to the metallic values left in the slag.

The oxygen used for metallic oxidation, concomitant with the desiliconizing and decarburizing, is calculated on the basis of the total oxygen used, less that used stoichiometrically for the decarburization and desiliconization, according to the method of Healy.[11] This is calculated for any given set of furnace conditions, e.g. oxygen input rate, furnace size, and temperature at start of oxidation for a variety of initial chromium, carbon, and silicon contents. For series 400 stainless steels, the fairly low manganese contents lead to the result that manganese behaves approximately like chromium under oxidizing conditions. Therefore, chromium and manganese are added together in the model for the calculation of oxygen consumption. Statistical methods are employed to obtain a linear equation for oxygen consumption in terms of the composition of the bath at the start of oxidation, all units being net tons. A typical oxygen consumption equation, for a temperature of 2730°F before the oxygen blow, an input rate of 500 cu ft per hr per net ton of charge and for a 70-ton furance is:

$$\begin{bmatrix}\text{Total } O_2\\ \text{Required}\end{bmatrix} = 0.012933 \begin{bmatrix}\text{Initial}\\ \text{Charge}\end{bmatrix} + 0.80328 \begin{bmatrix}\text{C in}\\ \text{Initial}\\ \text{Charge}\end{bmatrix} + 0.16376 \begin{bmatrix}\text{Cr + Mn in}\\ \text{Initial}\\ \text{Charge}\end{bmatrix} + 0.07147 \begin{bmatrix}\text{Si in}\\ \text{Initial}\\ \text{Charge}\end{bmatrix} \quad [2a]$$

From Fig. 1, the metallic content of the first slag is found as a function of slag basicity, converted to oxide content and thence to equivalent silicon not needed and this is subtracted from the total silicon requirement.

$$\begin{bmatrix}\text{Si Added}\\ \text{During Finishing}\\ \text{Period}\end{bmatrix} \leq \begin{bmatrix}\text{Si in}\\ \text{Final Metal}\end{bmatrix} \quad [3]$$

At the end of the reducing period, the bath frequently contains all the silicon permitted by the specification, and the third equation (actually an inequality) merely prevents the addition of silicon beyond the specified 0.4 pct.

$$\begin{bmatrix}\text{Cooling Effect of}\\ \text{Scrap and Alloy}\\ \text{Additions During}\\ \text{Reduction}\end{bmatrix} - \begin{bmatrix}\text{Electrical}\\ \text{Heat}\\ \text{Added}\end{bmatrix} + \begin{bmatrix}\text{Cooling}\\ \text{Effect}\\ \text{of CaO}\end{bmatrix} \leq \begin{bmatrix}\text{Heat Evolved}\\ \text{on Cooling}\\ \text{to 2910°F}\end{bmatrix} \quad [4]$$

$$\begin{bmatrix}\text{Cooling Effect of}\\ \text{Scrap and Alloy}\\ \text{Additions During}\\ \text{Reduction}\end{bmatrix} - \begin{bmatrix}\text{Electrical}\\ \text{Heat}\\ \text{Added}\end{bmatrix} + \begin{bmatrix}\text{Cooling}\\ \text{Effect}\\ \text{of CaO}\end{bmatrix} \geq \begin{bmatrix}\text{Heat Evolved}\\ \text{on Cooling to}\\ \text{3090°F}\end{bmatrix} \quad [5]$$

These two heat balance restrictions (again as inequalities) determine the conditions necessary to arrive at a bath temperature between 2910° and 3090°F at the end of the reduction period. Such a limitation is required for practical reasons, since it is usually desirable to cool the bath from the high temperature reached during the oxygen blow to a more reasonable level in order to protect the furnace. The cooling effects of the ferro-alloys added can be broken down into three portions. First, there is the heat of dissociation of the various carbides and silicides present at room temperature. Secondly,

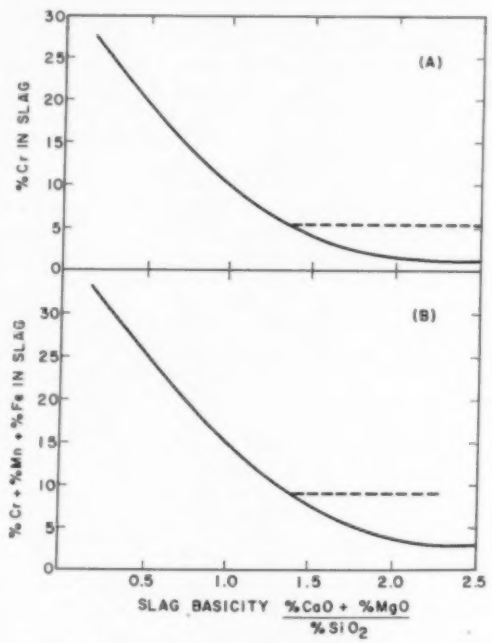


Fig. 1—Effect of basicity on concentration of (A) chromium and (B) chromium plus manganese plus iron in reduced slags, according to Rassbach and Saunders.

the resulting elements must be heated to the generally unknown temperature at the end of the oxidizing period by integrating their specific heats, and thirdly, their heat of solution in the metal must be considered. The cooling effect of the lime also operates in three ways: the heat necessary for raising its temperature to the temperature at the end of oxidation, the heat of oxidation of the silicon added, and the heats of formation of the calcium silicates in the slag. It might or might not be necessary to apply power at this stage of the heat to prevent the bath from freezing. The net effect is to cool metal and slag from the unknown temperature at the end of oxidation to somewhere between 2910° and 3090°F without allowing for heat losses from the furnace.

$$\left[1+\left(\frac{CaO+MgO}{SiO_2}\right)\right]\times\left[(Total\ Si)-(Si\ in\ Final\ Metal)\right]\frac{60.06}{28.06}=\left[Slag\ Weight\right]-M_xO_y \qquad [6]$$

Eq. 6 applies to the end of the reduction period, and M_xO_y represents the weight and average composition of metallic oxides including iron, chromium, and manganese. The MgO is derived from the furnace bottom and is assumed equal in weight to the SiO_2 formed during meltdown by oxidation of silicon (up to 0.5 pct) in the initial charge. Calcium oxide represents the lime addition required to establish the desired basicity ratio. The basicity ratio $\left(\frac{CaO+MgO}{SiO_2}\right)$ and the metallic oxides are derived from Fig. 1.

The temperature at the end of the oxygen blow shall not exceed a specified maximum, for example 3315° F. [7]

This statement is given in lieu of the very complex relations actually used in the calculation. The temperature limit has an extremely important influence on the outcome and is normally set as high as is consistent with refractory life. The relations between temperature and blowing rate, furnace size, metal composition etc., have been discussed[10] in some detail, and the equations used in calculations are based on the published data. The actual temperature equation is derived for the particular conditions specified in the same manner as described above for oxygen consumption.

The sum of chromium and manganese in the initial charge shall not exceed 18 pct. [8]

The sum of chromium and manganese in the initial charge shall be not less than 8 pct. [9]

These two restraints place arbitrary limits upon the composition of the charge within which the computations and conclusions are applicable. They are necessary because the linearized expressions for oxygen and for temperature after the oxygen blow are valid within these limits.

The chromium charged as 430 scrap shall not exceed 40 pct of the total chromium used. [10]

This restriction is based purely on an industry-wide average scrap availability. It simply excludes higher scrap charges from consideration in the present calculations.

The chromium added as 430 scrap after the oxidation period shall not exceed 10 pct of the total chromium. [11]

Restraint 11 assumes that usually not more than about one-quarter of the available scrap is suitable for charging after the oxygen blow. From a purely economic point of view, however, the less chemical work done on the scrap, the better. Hence, from this consideration, and from its value as a coolant, it might be better to introduce as much 430 scrap after oxidation as possible. If larger or smaller amounts of 430 scrap are available than are permitted by restrictions 10 and 11, the inequalities representing these restrictions can easily be modified to include the appropriate values.

To simplify computations, the oxygen and lime needed were not entered into the program directly,

Table I. Variables Used in the Stainless Steel Linear Program for the Results Described

	Assumed Composition*					Cost	
	Pct Cr	Pct Mn	Pct Si	Pct C	Pct Fe	¢/Lb	$/NT
Charge							
Steel scrap		1.00	0.10	0.50	98.40		38.40
430 scrap	16.50	1.00	1.00	0.08	81.42		107.14
Regular charge chrome	52.50		6.50	6.50	34.50	25.75(Cr)	
Refined charge chrome	53.00		1.40	4.30	41.30	26.50(Cr)	
3 pct Si refined charge chrome	53.00		3.00	4.30	39.70	26.50(Cr)	
10 pct Si refined charge chrome	50.00		10.00	3.80	36.20	26.50(Cr)	
Low-Cr High-C FeCr	59.50		3.50	5.00	32.00	28.25(Cr)	
High-C FeCr	68.50		1.50	4.50	25.50	28.75(Cr)	
Oxidation							
Oxygen							33.65
Reduction							
Lime							18.45
430 scrap	16.50	1.00	1.00	0.08	81.42		107.14
50 pct FeSi			49.00		51.00	14.6(Si)	
75 pct FeSi			75.00		25.00	16.4(Si)	
FeCrSi 40/43	40.00		43.00	0.05	16.95	28.25(Cr) + 14.6(Si)	
FeCrSi 55/24	55.00		24.50	0.04	20.46	32.25(Cr) + 14.6(Si)	
Low-C FeCr (0.10 pct max C.)	69.00		1.00	0.10	29.90	38.50(Cr)	
Simplex II	65.00		1.00	0.025	25.50	36.75(Cr)	
Power							
Finishing							
Low-C FeCr (0.10 pct max C.)	69.00		1.00	0.10	29.90	38.50(Cr)	
Simplex II	65.00		1.00	0.025	25.50	36.75(Cr)	

* Representative compositions arbitrarily assumed for the calculations reported in Tables II and III, and Figs. 3, 4, and 5.

but were taken into account in an economic sense by adding the cost of the associated lime and oxygen to the actual prices of the various materials used, on the basis of their chemical compositions and the time during the heat at which they were to be added.

The economic aspect of the program is limited strictly to the costs of the metallic materials, lime, and oxygen, and it is the sum of these costs which is to be minimized. Time and other *cost above* items are not included. Within the normal operating range, these latter factors essentially reflect equipment, e.g. transformer capacity and charging facilities, and human limitations. As pointed out by Blough[19] and Cotton,[20] these latter factors appear to be relatively independent of the materials ordinarily available commercially. Consequently, their inclusion was considered to introduce unnecessary complications in this generalized program. Moreover, materials are the major cost item in stainless steel ingot production, usually accounting for 80 pct or more of ingot costs.

With the program as outlined, knowledge of only the following operational conditions is needed for calculation of the lowest cost materials practice to fit both the technical and practical restrictions:

1) bath temperature at the start of the oxygen blow,

2) fraction of bath that is melted when the oxygen blow is begun,

3) oxygen input rate,

4) furnace size,

5) maximum temperature allowable at the end of the oxygen blow,

6) scrap availability and proportions suitable for back-charging, and

7) slag basicity desired at the end of the reducing period.

Of these factors, perhaps the third, oxygen input rate, requires further comment. As explained by Healy and Hilty,[20] the oxygen input rate is expressed in terms of cu ft per hr per net ton of initial charge. Furthermore, it refers to the total quantity of oxygen injected into the bath divided by the total elapsed time from the start of the blow until slag reduction is begun and not simply to the rate at which oxygen is discharged from a lance. Such an expression of the actual, effective rate of oxygen input is necessary because the furnace is continually losing heat, and any delays or interruptions of the blow influence the net result.

The number of materials that can be considered with the program is virtually unlimited. Over 30 different sources of chromium, iron, silicon, etc., have been included in various calculations that have been made to date, and more can be added without difficulty.

Typical results

The program is quite versatile in its applications. By inserting the proper constants in the equations,

Table II. Effect of Temperature After Oxygen Blow on Alloy Usage (Blow Begun at 2910°F)

Temp after O_2	°F	3225	3315	3405
Basicity	$\frac{CaO + MgO}{SiO_2}$	1.5	1.5	1.5
Blow rate	CFH/NT	500	500	500
Pct melted before O_2		100	100	100
Charge				
Steel scrap	Lb/NT	1000	893	855
430 scrap	Lb/NT	508	618	623
Refined charge chrome	Lb/NT	—	114	282
Reduction				
430 scrap	Lb/NT	204	206	208
FeCrSi 55/24	Lb/NT	67	99	83
FeCrSi 40/43	Lb/NT	—	—	26
Finishing				
Simplex II	Lb/NT	281	137	—
Materials cost	$/NT	139.77	132.63	124.87
Relative slag volume	Lb/NT	127	180	230
Cr in initial charge	Pct	5.56	9.99	14.33
Lanced oxygen	CF/NT	252	379	534
Lime	Lb/NT	65	92	112

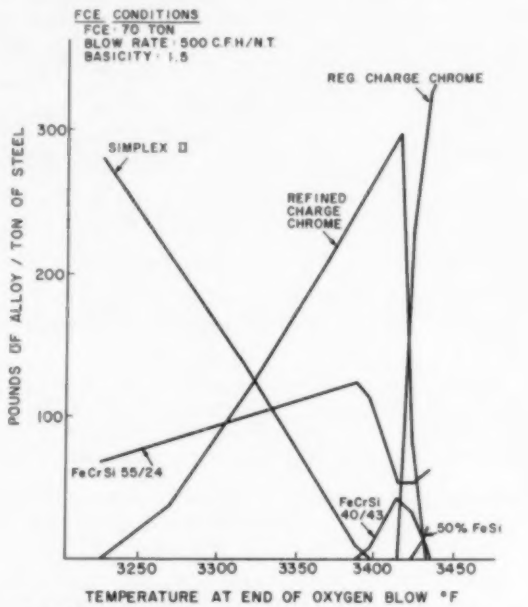


Fig. 2—Effect of temperature on optimum alloy usage after oxygen blow begun at 2910°F.

Table III. Effect of Several Operating Parameters

Temp before O_2	°F	2730	2910	2910	2910	2730
Temp after O_2	°F	3315	3315	3315	3315	3315
Basicity	$\frac{CaO + MgO}{SiO_2}$	1.5	1.5	1.5	1.1	1.5
Blow rate	CFH/NT	500	500	1000	500	500
Pct melted before O_2		100	100	100	100	75
Charge						
Steel scrap	Lb/NT	870	893	886	883	869
430 scrap	Lb/NT	628	618	610	625	633
Refined charge chrome	Lb/NT	191	114	99	111	118
Regular charge chrome	Lb/NT	—	—	—	—	86
Reduction						
430 scrap	Lb/NT	209	206	203	208	211
FeCrSi 55/24	Lb/NT	168	99	51	96	184
Finishing						
Simplex II	Lb/NT	21	137	186	145	—
Materials cost	$/NT	131.53	132.63	130.70	133.67	132.07
Relative slag volume	Lb/NT	280	180	101	151	330
Cr in initial charge	Pct	12.13	9.99	9.60	10.00	12.43
Oxygen (Lanced)	CF/NT	604	379	362	377	746
Lime	Lb/NT	147	92	55	77	164

it can be employed for calculation of the optimum charges and additions for producing Type 430 stainless steel in a specific shop, or in a particular furnace. Perhaps its greatest advantage, however, is in its use as a model simulating the melting operation for the purpose of estimating the probable economic effects of changes in various operating parameters.

In presenting these results, the authors wish to emphasize that they are illustrative and subject to qualitative interpretation only. They refer to a generalized case and to no specific practice. Furthermore, computations by this program relate to a particular price structure for scrap and ferro-alloys (in this instance the one prevailing in early October 1958) and any other price structure may substantially modify the results.

The results described here were obtained on our computer on the assumption of a 70-ton furnace making Type 430 stainless steel to a specification of 0.08 pct C (max), 0.4 pct Si (aim), and 16.5 pct Cr (aim), carbon being oxidized to 0.05 pct during the oxygen blow. Scrap availability was assumed to be 40 pct, of which one-quarter, equivalent to 10 pct of the total chromium requirement of the steel, was suitable for back-charging as a cool-off addition following the oxygen blow. Other parameters were varied as indicated. The materials from which the computer was permitted to choose in these calculations are listed in Table I.

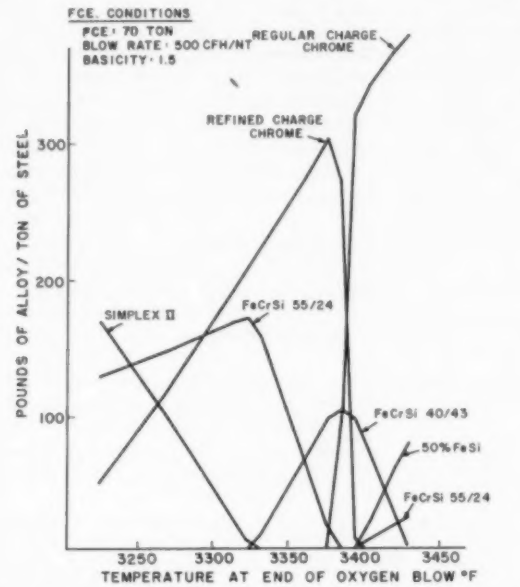


Fig. 3—Effect of temperature on optimum alloy usage after oxygen blow begun at 2730°F.

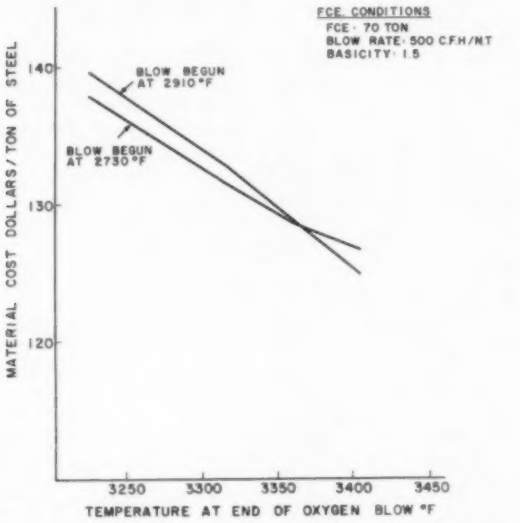


Fig. 4—Effect of temperature on minimum materials costs before and after oxygen blow.

Table I illustrates the effect of temperature at the end of the oxygen blow on optimum materials usage and cost for one set of operating conditions. In addition to the parameters mentioned in the preceding paragraph, these conditions were assumed to be as follows:

Oxygen input rate ..... 500 cu ft per hr per ton of charge

Bath temperature at start of oxygen blow ..... 2910°F

Basicity of reduced slag ..... $\frac{CaO+MgO}{SiO_2} = 1.5$

The results of Table II emphasize the great importance of maximum temperature limitations in the economics of the process.

Table III lists the results of computations indicating the influence of starting the oxygen blow at different temperatures, changing the oxygen input rate, lowering the basicity of the reduced slag, and starting the oxygen blow before the bath is completely melted. For these calculations, the maximum temperature permitted at the end of the oxygen blow was assumed to be 3315°F. Such a temperature is believed realistic, although possibly on the high side of the practical range for a 70-ton furnace.

The trend of ferro-alloy requirements for lowest materials cost as a function of temperature at the end of the oxygen blow is illustrated by Fig. 2 for a bath temperature of 2910°F. at the beginning of oxygen injection. Fig. 3 shows a similar trend for an oxidation period started at 2730°F. The trend of lowest materials costs for both cases is demonstrated by Fig. 4. All of these charts were computed on the basis of an oxygen input rate of 500 cu ft per hr per ton of charge and of basicity ratio $\left(\frac{CaO+MgO}{SiO_2}\right)$ of 1.5 at the end of slag reduction.

For the most part these results are self-explanatory, so that further elaboration of them is hardly needed. A few points in their connection, however, may be worth additional comment.

The first column of Table II illustrates how a possible requirement for limiting the bath temperature to a rather low level after the oxygen blow, because of poor condition of the furnace or any other reason, severely restricts the amount of chromium that should be included in the charge. For this calculation, incidentally, it was necessary to relax Restraint 9 of the program which specifies that the chromium plus manganese contents of the charge must not be less than 8 pct. Consequently, the result of this calculation is somewhat more uncertain than the others. The fact that the computer failed to select even all of the 430 scrap available for the charge is, nevertheless, considered indicative of the true situation.

The last column of Table II and the portions of Figs. 2 and 3 above approximately 3300°F presumably do not apply in the practical sense to 70-ton furnaces, because attainment of such temperatures may lead to damage in large furnaces. Nonetheless, they are of considerable interest for the general information they provide. They demonstrate that under some operating conditions, blending of ferro-alloys within the same class may be desirable, if minimum materials costs are to be obtained. The last column of Table III indicates that such blending may be appropriate in practices involving more reasonable temperatures, depending on the other conditions of the heat.

This particular example is a good illustration of how the technical and practical considerations of the program operate by the blending of materials. It calls for a blend of high-carbon ferrochromium alloys in the charge. The assumption of a bath that is only 75 pct melted at the start of oxygen injection means that more heat can be generated during the oxygen blow than is the case in the other examples in Table III. The higher silicon and carbon contents of *regular charge chrome* as compared to *refined charge chrome* can provide some of the additional fuel for this heat; however, excessive amounts of silicon and carbon would cause the temperature limitation to be exceeded which, in a practical case, might mean severe furnace damage. Consequently, the amount of *regular charge chrome* that should be used in limited. The computer, therefore, blended *refined charge chrome* and *regular charge chrome* to provide the proper balance among silicon, carbon, and chromium to satisfy the chemical and thermal requirements of the process in the most economical way.

Although blending such as that just described may be desirable for greatest economy under some operating conditions, it presumably introduces practical problems in materials handling, maintaining stocks of a variety of ferro-alloys of slightly different compositions, etc., that may be a nuisance from the melter's viewpoint. The examples in Table III suggest that this approach can be used to identify small changes in practice that will eliminate the problems and may even improve the economics.

The calculations of relative slag volumes appearing in Tables II and III are of interest, even though they are somewhat idealized. They consider only slag that is generated by the chemistry of the process and make no allowance for slag-forming agents, other than silicon, that may be included in the meltdown charge. Nevertheless, their relation to each other is significant, and they illustrate the rather wide range of slag volumes that may be generated by different practices. Larger slag volumes, of course, usually mean lower chromium recovery. These results tend to confirm what operators have long suspected, namely, that the practice giving the lowest slag volume and highest chromium recovery is not necessarily the most economical practice from the overall materials standpoint.

Summary and conclusions

A mathematical method of linear programming has been applied to stainless steelmaking using Type 430 as the example. The method makes it possible to handle the numerous complex relations among the many variables of charge and practice in order to arrive at the optimum compromise to secure minimum cost of materials consistent with both the fundamental chemistry and the practical considerations controlling the melting process.

An important advantage of the method is its ability to provide a rapid means of identifying and evaluating the significant factors contributing to the cost of the process. Our computer, for example, obtains one complete solution of the program in approximately 5 min. Thus, the linear programming model can be used to simulate the melting operation for studying the influence of operating variables with far greater speed and much less expense than is possible by conventional experimental procedures. Similarly, the technique furnishes a fast way of estimating practice changes that may be desirable as a result of changes in the price structure of raw materials.

The program as outlined in this paper applies to generalized practices. It is capable, however, of expansion to include items which are characteristic of any operating practice or particular shop, such as variables of furnace time, refractory consumption, power demand, or materials availability.

The linear programming approach as applied here is believed to offer an excellent means of utilizing, for practical purposes, the vast amount of fundamental data that are being produced by the various researches on the physical chemistry of steelmaking. By combining these data with the available operating and economic data in the form of linear programming models, many other problems of the steel industry may be greatly clarified.

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Observations on STEELMAKING RESEARCH IN THE USSR

"Soviet engineers are on the trail of new ideas" . . . some of them are discussed in this article, based on a study of the steel plants and research institutes of the USSR.

by John F. Elliott

There is ample evidence to show that the Soviet steel industry is a highly favored segment of the Soviet economy. Over the past 26 years its impressive growth in size, capacity, and technology has resulted from lavish expenditure of funds and manpower. Soviet leadership has also provided it with scientific and technical support in the form of research programs and educational facilities for training scientists and engineers. Perhaps the best indication of the technical prestige enjoyed by the steel industry is the fact that its leading technical personality, Academician I. P. Bardin, is also vice president of the Soviet Academy of Science.

The scientific and technical needs of the Soviet Steel Industry are being met by an extensive program of research and development that is jointly supported by the Soviet Academy of Science and the steel industry itself. It appears that the Academy plays the key role in directing this joint venture. Technical activities for the industry are carried out in four significant areas: 1) Fundamental research; 2) Applied research; 3) Process development; and 4) Process control. This discussion covers the first three areas. The fourth, nevertheless, is important to the steel works and it appears that many of the steel plants are adequately staffed with metallurgists to meet their needs in process control.

Research pertinent to steelmaking is done in universities, scientific institutes, technical institutes for teaching, and research institutes which are supported and administered directly by the Academy of Science. Research and development programs are not only sponsored by the central government and the central steel industry, but also by the several national governments, i.e., The Soviet Socialist Republic of Ukraine and that nation's steel industry. However, it is evident that the Soviet Academy of Science in Moscow exercises leadership over and retains control of the programs for steelmaking research (and, all other researh as well). For this reason and because of the Academy's direct operation of several institutes for ferrous metallurgical research—such as the A. A. Baikov Institutes in Moscow and Leningrad, and its general direction of the Central Institute for Ferrous Metallurgical Research in Moscow— it will continue to be dominant in directing the technological advancement of Soviet steelmaking.

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Fundamental research

Perusal of current Russian scientific journal abstracts reveals that much fundamental research is being done on the properties of elements and compounds, and on the thermodynamics and kinetics of reacting systems pertinent to steelmaking. This work is being carried out in the universities, scientific institutes, teaching institutes, and the Academy-sponsored research institutes. Some very ingenious studies were observed. To illustrate the type of research being done, some of the experimental programs seen in Moscow are listed below:

1) **Transformations in very-high purity iron:** A modified differential-thermocouple technique is being used for this work by members of the A. A. Baikov Institute.

2) **Structure of liquid alloys:** At the Baikov Institute, Moscow, the relative magnetic susceptibilities of liquid Fe-Co, Ni-Co, and Fe-Si alloys have been measured in equipment sketched in Fig. 1. The magnet has a strength of approximately 16,000 gauss. The sample is held in an alumina crucible at 1600°C. The furnace is water-jacketed to protect the magnet from high temperatures.

3) **Fe-Ni-O System at 1600°C:** The oxygen potential at oxide saturation for the binary Ni-Fe system has been measured by equilibrating the metal and slag phases with H_2O-H_2 mixtures. Results indicate that the slag phase is virtually pure iron oxide for compositions in the metal phase from pure iron to approximately 25 pct Fe. This work is being done at the Baikov Institute, Moscow.

4) **Slag metal distribution:** Shvartzmann at the Central Institute for Ferrous Metallurgical Research is measuring the distribution of columbium between a steelmaking-type slag and an iron melt with the system shown in Fig. 2. Pellets of the powdered slag containing a radioactive isotope of columbium (Cb^{95}) are dropped periodically on the surface of the metal. The slag melts, passes across the surface, and is absorbed by the porous MgO crucible. Samples from the metal are *counted* periodically. When the count of successive samples becomes constant, it is assumed that equilibrium is reached between metal and the slag composition as dropped.

Other studies in progress are the measurement of activities in binary liquid iron systems by a free

evaporation technique, the determination of viscosities of liquid iron alloys, and measurement of the activity of carbon in gamma iron by CO/CO_2 equilibration.

Applied research

Great emphasis is being placed on applied research, especially in the institutions under immediate direction of the Academy of Science. While much of the work is still in the laboratory stage, industrial applications are being pushed ahead. A few of the most interesting applied programs are:

1) **Vacuum purification of metals:** Pure metals are being prepared by converting the metal to a carbide and then reacting a balanced mixture of oxide and carbide under vacuum at an elevated temperature. Ductile vanadium, containing 0.01 pct C and 0.01 pct O and also pure chromium, has been produced at the Baikov Institute. Apparently some work on the vacuum reduction of iron oxides is also underway.

Vacuum purification of powdered molybdenum and columbium in 100-lb lots is being studied at the Moscow Steel Institute (teaching).

2) **Flow characteristics of metallurgical systems:** At the Central Institute for Ferrous Metallurgical Research, Moscow, considerable work is being done on the characteristics of the flow of gases in metallurgical furnaces and in oxygen lancing procedures. Plexiglass models of tuyères, bessemer and LD vessels, mixers, and other types of vessels were observed.

3) **Levitation melting:** The techniques and limitations of levitation melting are being studied intensively at the Baikov Institute, Leningrad. Multiple unit coils have been used on a small scale.

The Second Symposium on the Application of Vacuum to Metallurgy had a number of papers covering the kinetics of reduction of oxides in steel melts, vacuum consumable-arc melting of ball-bearing steels and refractory metals, and the gas content of ferro-alloys.

Process development

It appears that the Soviet scientists and engineers working in iron and steelmaking have their greatest competence in process development. It also appears that their system, guided by the Academy of Science, is able to overcome effectively the many obstacles that lie between the conception of an idea and its practical use in industry. The ingenuity and imagination being exercised in the development programs is striking. Some interesting developments are:

1) **Sintering:** At the Ukrainian Institute of Ferrous Metallurgy an interesting study of sintering is underway. The general variables of the process—such as temperature, pressure, mineralogical transformations, and bed particle size—are being pursued. One experiment observed was the production of a passably good piece of sinter under reduced pressure with only 2 pct fuel.

2) **Blast furnace:** The Soviet steel industry appears to be wedded to the blast furnace as the major means for reducing iron ores on a large scale. This might be expected in view of their impressive achievements in blast-furnace practice. Under the direction of Academician I. P. Bardin, they are continuing their work on gas flow in the crucible and bosh regions of the blast furnace. Here experiments in the combined injection of oxygen and natural gas through the tuyères to reduce coke rates and increase production are being conducted. They are also working to improve the burdens physically, toward complete self-fluxed burdens and higher top-pressures on all their blast furnaces.

3) **Direct reduction:** Apparently limited effort is being directed toward *non-blast furnace* methods of reducing iron ores, but nothing specific was learned of it.

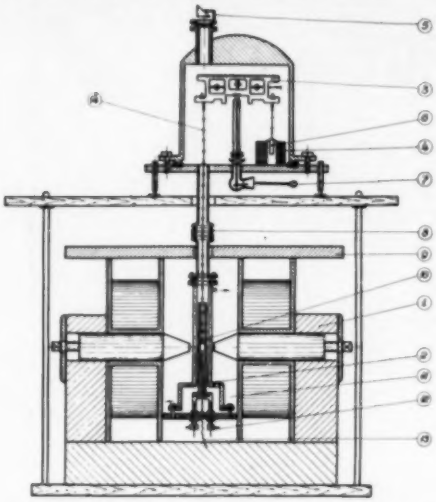
4) **Arsenic in ores:** Use of Kerch ore results in up to 0.2 pct As in the hot metal. The problem is being approached from two directions: a) To determine the effect of arsenic on the mechanical properties of steel and establish the levels that can be tolerated in various steel products. Arsenic is considered to have about one-fifth the embrittling effect of phosphorus for equal concentrations. Surprisingly, there was some thought that arsenic enhances the low-temperature impact properties of some steels. b) Self-fluxing sinters preclude elimination of arsenic in the sintering process; so, an oxidizing pre-roast is being considered.

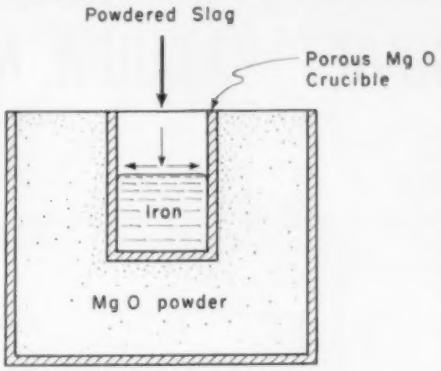
5) **Oxygen in steelmaking:** Because of the need for other facilities, all the major steel plants in the Soviet Union, with the exception of Zaporostahl and Dniepropetstahl in the Ukraine, do not have equipment for producing oxygen on a sufficiently large scale for full use in steelmaking furnaces and blast furnaces. However, they intend to equip all open hearth shops with oxygen roof lances and oxygen for combustion as soon as possible. It is reported that approximately 50 pct of the steel will be made in open hearth furnaces in the steel plants being built or to be built. The other half of production will be from LD-type converters. Apparently, a rotor-furnace similar to the ones in Oberhausen, Germany, is in operation at Azovstahl near the Caspian Sea.

6) **Induction stirring:** Induction stirring is being tried on a plant scale at Dniepropetstahl. One 50-ton electric furnace is so equipped, and each of the three new 50-ton units being installed will have stirrers.

7) **High-Vanadium hot metal:** Under the direction of A. M. Samarin, the Baikov Institute, Moscow and the Nova Tula experimental steel plant are developing an oxygen process for treating hot metal which contains vanadium and may also be high in phosphorus. Some European Russian ores yield hot metal containing up to 0.5 pct V; the level is 0.05 pct for some Siberian ores. Laboratory work and plant experiments in a 10-ton top-blown oxygen converter are directed toward a three-stage process. In the first stage the metal is blown in a ladle or an acid-lined vessel, with an oxygen lance very close to the surface. The temperature of the metal is kept below 1300°C, and the vanadium is carried off in a manganese-silicate slag. A basic high-phosphorous slag used for fertilizer production is produced in the second stage by top-blowing in a basic-lined vessel. The third stage of top-blowing with oxygen for decarburization is carried out in the same vessel or in a third unit.

8) **Continuous casting:** The Soviet steel industry is currently installing a 140-ton per hr continuous casting machine at Stalinor (Dombas Region). Four slabs, each with a cross-section of 150x600 mm, are cast simultaneously. Extensive exploitation of this process is planned for the near future.





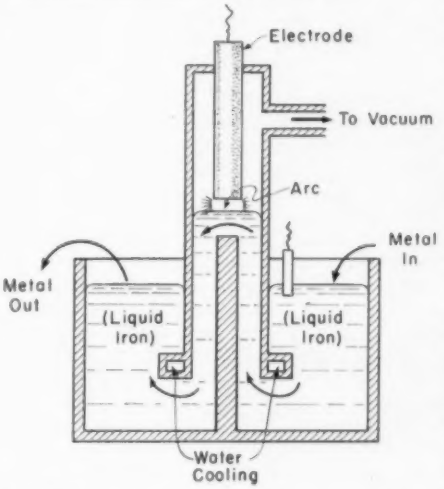


Fig. 1 (left)—Apparatus for measuring relative magnetic susceptibilities of liquid alloys. Fig. 2 (right)—System for measuring slag-metal distribution. Fig. 3 (below)—Equipment for continuous desulfurization of hot metal by vacuum-arc treatment.

9) **Continuous steelmaking:** The possibility of making steel on a continuous basis is being given some attention. Academician Bardin has long dreamed of it and preliminary plans for blowing oxygen into the hearth of a blast furnace to produce a low-carbon product from the furnace are being considered. A second idea is to put a syphon on a large blast furnace so that a stream of metal will flow from it continuously. As the stream cascades down a series of small hearths, one oxygen lance per hearth would oxidize the iron, and low-carbon, low-silicon metal would flow from the last hearth.

10) **Continuous vacuum desulfurization of hot metal:** A 15-ton-per-hr experimental unit (shown in Fig. 3) for vacuum desulfurization of hot metal is being built at the Nova Tula steel works. The arc is used to compensate for heat losses. The idea was conceived at the Baikov Institute, Moscow.

11) **Vacuum degassing of steels:** Both ladle and stream degassing of liquid steel have been practiced for several years. The engineers said that a 250 ton casting for a generator rotor recently had been vacuum poured. Although operations may be handicapped by pumps of limited capacity, the technique has been applied in a very practical way. The 30-ton ladle degassing unit seen at Dniepropetstahl was very simple and easy to operate. It is about four years old and was installed in a very convenient location in a medium-sized electric furnace shop. It may be assumed that a great many heats have passed through it, and the steel plant engineers have learned much about its application to many grades. This direct and utilitarian approach typifies the vigor with which new ideas are exploited.

General analysis

The engineers and scientists who are working to improve the technology of Soviet steelmaking are a bold and imaginative group. Their greatest competence appears to lie in process development. On the other hand, perusal of their literature shows a tendency to what may be called an over-eagerness to publish, and in the scientific areas they seem to miss the steadying hand and discipline of a few old and experienced minds. With the backing of the Soviet Academy of Science, they appear certain to bring to all areas of steelmaking an advanced technology equal to the one they now enjoy in blast furnace. Some of the ideas being developed may appear impractical, but they recognize that some gambles are necessary if progress is to be made. They delight in working with the unconventional, both in the laboratory and in industrial operations.

There is a lesson in this picture for the metallurgists and the steel industries of America and the Western World. The Soviets have a superior blast furnace performance. What they have accomplished should be analyzed carefully and applied where possible. However, if we are content with just this, we will again be behind in a year or two because the Soviet engineers are on the trail of new ideas. In other aspects of steelmaking, present Soviet technical efforts could easily offset, in a few years, the edge which the American steel industry currently enjoys. Clearly, we face a technological challenge which must be met. To do this requires a well-planned and co-ordinated program of good scientific research . . . intensive study of the reactions and chemical systems for iron and steelmaking . . . and a vigorous and bold exploitation of promising new ideas (including some having considerable risk).

It is not so much the current position of Soviet technology of steelmaking that should be of concern, but rather the direction in which it is moving in its research and development. We must meet this challenge with a greater understanding of what needs to be done and with the will to do it.

SOVIET VACUUM METALLURGY

During a visit to the USSR, an intensive study by the author revealed the broad scope of Soviet research in and development of vacuum metallurgical techniques.

by A. M. Aksoy

DURING 1958, five Americans attended the second Moscow symposium on the application of vacuum to metallurgy. The symposium was sponsored by the committee on physical chemistry of steelmaking of the A.A. Baikov Institute of Metallurgy, Academy of Science of the USSR. It lasted four days and was attended by a total of 280 people. Except for about 25 people from foreign countries—West Germany, East Germany, Lichtenstein, Poland, Hungary, Czechoslovakia, China, and the US— Soviet citizens made up the audience. It was a comprehensive conference, addressed to metallurgists working with vacuum in research, development, and production. The guiding hand of the Conference was provided by Dr. A. M. Samarin, Deputy Director of the Baikov Institute of Metallurgy, who is well known in this field and co-author of a large number of papers presented there.

During the remaining portion of our 10-day stay, we had the opportunity of visiting several research institutes, steel plants, and a vacuum equipment plant. Among the research organizations visited were Central Scientific Institute for Ferrous Metallurgy, Moscow Steel Institute, and Baikov Institute of Metallurgy. The scope of vacuum metallurgy in the Soviet Union appears to be very broad. In these institutes research and development work is carried out on reduction, refining, melting, thermal treatment, and the properties of vacuum-processed materials.

The impressions and comments made here are based on 1) the data presented at the Symposium, 2) visits made to various institutes, 3) discussions held with individuals engaged in various phases of vacuum metallurgy, and 4) literature made available to us.

Vacuum induction melting

Approximately one-fifth of the symposium was devoted to vacuum induction melting. Data were presented on the melting and properties of nickel-base high-temperature alloys, stainless steels, and magnetic alloys.

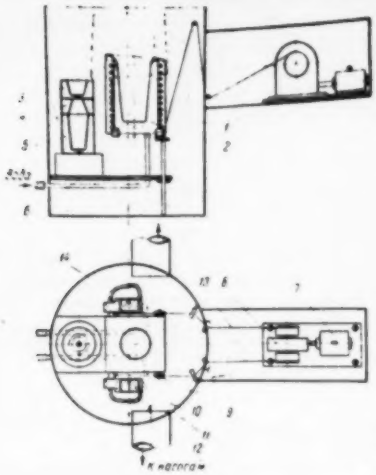
The reports on nickel-base high-temperature alloys dealt with the effect of pressure on gas content and cleanliness, deoxidation in vacuum by various elements, and improvement in properties. For example, the gas content and cleanliness of a Nimonic-type alloy melted at 1 atm, 10^{-3} mm, and 10^{-5} mm were compared by Chuprin (Table I). The oxygen contents of heats melted at 10^{-3} mm and 10^{-5} mm pressure were 75 pct and 10 pct, respectively, of that melted at 1 atm. In another investigation, lowest oxygen content was said to be obtained in vacuum melting when C + Mg + Mn + (Ca-Si) were used. Kashin described an investigation in which the vacuum melting of an alloy, similar to Nimonic 95, eliminated precision casting defects found in air-melted buckets due to oxide and nitride films. In addition, a 200 pct improvement in stress-rupture life and 100 to 150 pct improvement in elevated-temperature ductility were obtained. As a result of vacuum melting, the rejection of parts made from various high-temperature alloys was reduced significantly. These improvements are similar to those reported in the US.

The report on magnetic alloys was an extension of the work carried out on silicon steels by Garnyk and Samarin at the Baikov Institute. Vacuum melting permitted the production of alloys up to 6 pct Si with low oxygen, down to 0.0016 pct. Carbon and sulfur contents were also lowered. Reduction of these impurities and high silicon content decreased the core losses and improved cold rollability.

Lintschevsky discussed vacuum melting of 18-8 steel and compared its properties to two commercial steels comparable to Types 304 and 321. The relationships of oxygen content to toughness and ductility, and of carbon content to strength were graphically presented. As the oxygen content increased from 0.001 pct to approximately 0.01 pct, impact strength and ductility of alloys containing less than 0.02 pct C decreased sharply. Above 0.01 pct, oxygen did not have any significant effect. Tensile strength increased sharply as the carbon content increased from 0.01 to 0.04 pct. Further increase in carbon only slightly increased the strength. Corrosion resistance of vacuum-melted steels, as measured by weight loss in boiling nitric acid, was 20 to 100 times better than commercial steels. This was the most comprehensive study on vacuum-melted steels that has come to this writer's attention.

The various alloys referred to above were melted in furnaces having a capacity of from 22 to 330 lb.

A. M. AKSOY is manager, Applied Research Laboratory, Crucible Steel Co. of America, Syracuse, N. Y.



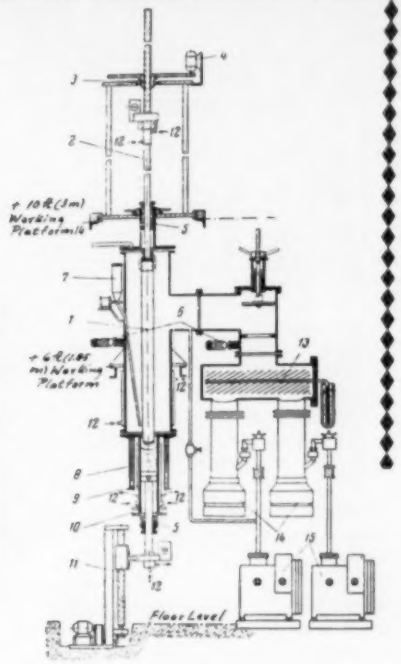


Fig. 1 (below)—A 25-lb vacuum induction furnace at the Baikov Institute of Metallurgy. Fig. 2 (left)—A 330-lb vacuum induction furnace. Fig. 3 (right)—A vacuum arc furnace with 4 to 6-in. mold at the Baikov Institute.

Fig. 1 shows the experimental vacuum induction furnace at the Baikov Institute. The characteristics of the 330-lb furnace are shown in Fig. 2. Furnaces of 1100-lb and 6600-lb capacity have been designed but have not yet been built. The mold transfer in these furnaces is horizontal, similar to some of the production furnaces in the US.

Refractory practice is also similar to that used in this country. One interesting development is autocrucible melting. A charge of coarse powder is held within a shell of fine powder backed by refractories inside an induction coil. The particle size and frequency of the power supply are selected so that coupling is primarily with the central charge, with the result that it melts within a sintered outer shell of the same metal and can be poured like a skull furnace. This seems to be practical only on a small scale.

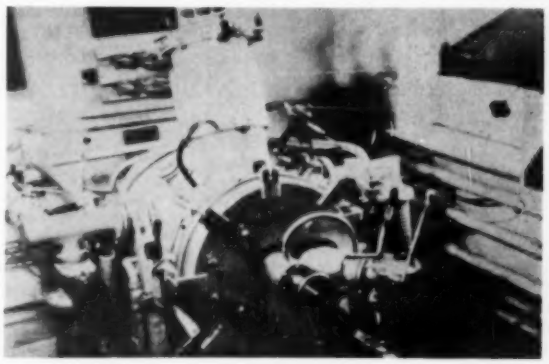
Vacuum arc remelting

Vacuum arc remelting of steels and super alloys is relatively new in the Soviet Union. However, a number of alloys are vacuum arc remelted on an experimental basis. Experience with ball bearing steel of AISI 52100 type was discussed in two papers. The work carried out at the Baikov Institute was described by Okorokov. There ingots 4 in. in diam weighing approximately 110 lbs were vacuum arc remelted at pressures of 10^{-2} to 10^{-4} mm of Hg. The effects of melting variables were thus studied systematically. In addition, the geometry and temperature of the molten pool at the end of the melting cycle were determined. Oxygen and sulfur contents and cleanliness of triple vacuum arc remelted steel are shown in Table II. Fig. 3 shows a small vacuum arc furnace at the Baikov Institute of Metallurgy.

In the second paper, Belkov, of the Ball Bearing Institute compared the quality of air-melted and vacuum-arc remelted 52100 type steel produced in large furnaces. Statistical distribution curves for oxide, sulfide and silicate type inclusions showed a marked improvement in cleanliness for vacuum arc remelted steel.

Vacuum degassing

Vacuum degassing of steel is widely used in the Soviet Union. According to the reports, there are 10 ladle-degassing and four stream-degassing units.



The capacity of these units varies from 15 to 120 tons. Ladle degassing is apparently being used for ladles up to 50 tons and stream degassing for larger tonnages. Vacuum degassing is used for bessemer rail steel, transformer steel, alloy constructional steels, stainless steels, and cast steels.

The vacuum maintained in degassing operations varies from a few millimeters up to 100 mm, which is higher than those employed in Germany and the US. In some installations older pumps are being replaced by more efficient pumps of larger capacity.

Several papers presented at the Symposium discussed the properties improved and benefits derived from vacuum treatment. Figures on gas reduction varied from one source to another. In general, hydrogen was lowered to 1 to 3 ppm, and flaking was eliminated. Initial oxygen content was reduced by 40 to 70 pct and initial nitrogen content by 30 to 50 pct. Cleanliness of various types of steel was also improved significantly. Statistical analysis of commercial vacuum-treated bessemer steels showed a two to fourfold increase in impact strength at temperatures from −40° to 68°F. Transition tempera-

tures of vacuum-treated steel were lower; vacuum-treated steels were also found to be free of center segregation and cracking. Moreover, improvements obtained for vacuum-treated transformer steel were similar to those described under vacuum induction melting, but to a lesser extent. In the case of stainless steels, rejections due to hair cracks were reduced to 10 to 20 pct of their previous level.

Desulfurization in vacuum

Of particular interest were the studies conducted on vacuum desulfurization. The equilibrium and kinetics of sulfur removal in vacuum from liquid iron alloys (Fe-S, Fe-S-C, Fe-S-C-Si and Fe-S-C-Si-Mn) are being investigated at the Baikov Institute. This work consisted in vacuum treatment of small melts at 10^{-5} mm pressure, using a *partial pour* technique to determine the sulfur drop. Temperatures during the treatment varied from 1260° to 1570°C, depending on the alloy. The desulfurization data obtained is shown in Table III. Results show that Si lowers minimum sulfur content attainable, and Mn accelerates desulfurization.

As a result of these studies, the design and construction of a pilot desulfurization unit at Nova Tula steel plant is being considered. This unit would operate at 10^{-3} mm pressure, with a barometric leg continuous feed from the atmosphere. The temperature would nominally be 1260°C, with a direct arc being used to add enough heat to compensate for heat losses in transfer and evaporation. A flow diagram incorporating both vacuum desulfurization and vacuum degassing reflects their thinking regarding future steel production.

Table I. Reduction in Gas Content of a Ni-Cr High-Temperature Alloy (Based on gas content at 1 atm)

Pressure	O_2	H_2	N_2
1 atm	100	100	100
10^{-3} mm	75	10	50
10^{-6} mm	10	10	20

Table II. Oxygen and Sulfur Content and Cleanliness of Ball Bearing Steel (52100 Type)

	Pct O_2	Pct S	Overall Cleanliness Rating (Analogous to JK Rating)
Air melted	0.0034	0.038	2-4
Single vacuum arc remelted	0.0025	0.024	1-2
Double vacuum arc remelted	0.0015	0.016	½-1½
Triple vacuum arc remelted	0.0008	0.008	½-1 (occasional)

Table III. Desulfurization Data

	Composition (Balance Iron), Pct				Pct S (Min After Vacuum Applied)				
No.	C	Si	Mn	P	0	5	10	15	20
1	4.4	—	—	—	0.24	0.22	0.18	—	0.16
2	4.81	0.15	—	—	0.23	0.21	0.18	0.17	0.16
3	4.10	0.72	—	—	0.24	0.19	0.13	0.11	—
4	3.60	2.00	—	—	0.23	0.12	0.11	0.08	0.06
5	4.86	0.60	0.47	—	0.21	0.14	—	0.11	0.09
6	3.74	0.60	1.22	—	0.23	0.13	0.10	0.08	—
7	3.88	0.60	3.84	—	0.30	0.07	0.06	0.04	—
8	3.50	1.17	0.66	0.06	0.045	0.022	0.007	0.007	0.001
9	3.45	1.96	0.90	0.09	0.067	0.015	0.002	0.001	—
10	3.70	0.39	1.44	1.43	0.060	0.041	0.032	0.033	—

Notes: (1) Pressure: 10^{-2} mm for all alloys.
(2) Temperature: 1300°C for alloys 1 to 7 and 1260°C for alloys 8 to 10.

Vacuum reductions

In the Soviet Union considerable emphasis is placed on the production of metal powders of relatively high purity by carefully balancing carbon and oxygen content. The gas content of certain metal powders is reduced by vacuum treatment at a small installation in the Moscow Steel Institute. The installation consists of a bell-type furnace, charged with about 100 lbs of metal powder. The metal powder is charged into a cylindrical graphite container, which is placed into the brick chamber of the furnace in a vertical position. The furnace is then evacuated to 10^{-4} mm pressure, and the temperature raised. The oxygen and nitrogen contents of chromium powder were reduced in this setup from 0.0250 pct to 0.0065 pct and from 0.082 pct to 0.024 pct respectively, at 1200°C.

Vacuum rolling

Vacuum rolling was discussed by Gurevitch, who built an experimental unit at the Institute of Ferrous Metallurgy to study the hot deformation of alloys high in chromium. This unit consisted of a cylindrical vacuum chamber in which a heating furnace, cooling pad, and rolls were placed in a transverse direction. It was equipped with inlet and outlet locks and was capable of operation at 10^{-5} mm pressure. The investigation reported covered the vacuum rolling of five metals or alloys: levitation melted chromium, vacuum induction-melted chromium, chromium plus 40 pct iron alloy, 530 Steel (19 pct Cr, 28 pct Ni, 3 pct Mo), and high-purity iron. It was found that greater reduction can be given to these gaseous-contamination-sensitive materials before cracking, and they can be rolled at lower temperatures.

Ultrasonic treatment of molten metals

At the same Institute, a small laboratory unit and a large pilot-plant installation for ultrasonic treatment during ingot solidification were seen. The pilot-plant installation was operated under vacuum and consisted essentially of a 110-lb crucible in a bell-type tank. Energy for the transducer (magnetostrictive) coil on the mold base plug was 150 kw at 10,000 cycles. Examination of the cross-sections of several ingots made with and without ultrasonic treatment revealed a marked difference; those made with ultrasonic treatment had uniform fine grain structure except a thin layer on the outside.

References were made to studies on levitation melting, drip-pool melting, zone melting, and electron bombardment melting, but all these were on a small laboratory scale.

Conclusion

In conclusion, the scope of vacuum melting in the Soviet Union is broad. Considerable effort is being devoted to the fundamentals of vacuum metallurgy at various research institutes. The quantity and quality of the work carried out at the Baikov Institute is impressive. The transition of worthwhile projects to production seems to be well co-ordinated. Vacuum degassing is used extensively in the steel industry, and plans are underway to construct larger vacuum induction and vacuum arc furnaces, yielding more production as the need for vacuum-melted materials increases.

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AIME NEWS

Division Officers for 1960 Nominated by Metallurgical Society

The Nominating Committees of the Extractive Metallurgy, Iron and Steel, and Institute of Metals Divisions have submitted their nominees for officers and Executive Committee members to serve in 1960.

Extractive Metallurgy Division nominees to begin service in February, 1960, following the AIME Annual Meeting are: Chairman (automatic), Reinhardt Schuhmann, Jr., Purdue University; Chairman-elect, Richard C. Cole, Vitro Uranium Co., Div. of Vitro Corp. of America; Secretary, R. W. Shearman; Treasurer, T. D. Jones, American Smelting and Refining Co. Executive Committee officers (1960-1963): W. A. Krivsky, Union Carbide Metals Co.; G. H. Turner, Consolidated Mining and Smelting Co. of Canada, Ltd.

The Institute of Metals Division has named the following individuals to serve in 1960: Chairman, T. A. Read, University of Illinois; Senior Vice Chairman, J. H. Jackson, Battelle Memorial Institute; Vice Chairman, David Swan, Linde Co.; and Secretary-Treasurer, D. C. Johnston. Those to serve on the Executive Committee for three years are: A. T. Cape, Consultant; C. L. McCabe, Carnegie Institute of Technology; and N. E. Promisel, Bureau of Aeronautics, Dept. of the Navy.

The Iron and Steel Division has submitted the following nominees: Chairman, J. J. Golden, U. S. Steel Corp.; Chairman-elect, Gerhard Derge, Carnegie Institute of Technology. Nominees to serve on the Executive Committee from 1960-1963 are T. D. Hess, The Youngstown Sheet & Tube Co.; and R. A. Lubker, Alan Wood Steel Co. S. J. Dougherty of Weirton Steel Co. will serve a one-year term.

J. S. Smart, Jr. Nominated President-Elect of The Metallurgical Society

J. S. Smart, Jr. has been nominated as Vice President and President Elect of The Metallurgical Society for a term of one year, beginning February, 1960, according to an announcement by W. R. Hibbard, Jr., chairman of The Metallurgical Society's Nominating Committee.

Mr. Smart automatically becomes President of the Society in 1961.

The President-Elect, who has also been chosen as a director of the Society from the IMD, is the General Sales Manager with American Smelting nd Refining Co. His biography appears under **Directors,** p. 473.

In other action, the Extractive Metallurgy Division has nominated the following men to serve on The Metallurgical Society's Board of Directors, beginning February, 1960: A. W. Schlechten, Missouri School of Mines, three-year term; and Reinhardt Schuhmann, Jr., Purdue University to serve a one-year term coincident with his office as Chairman of EMD.

The Institute of Metals Division, meanwhile, has nominated J. H. Scaff, Bell Telephone Laboratories, to serve a three-year term; and T. A. Read, University of Illinois, will serve a one-year term on the Board of Directors.

The Iron and Steel Division nominees to The Metallurgical Society's Board of Directors are K. L. Fetters, The Youngstown Sheet & Tube Co., for a three-year term; and J. J. Golden, U. S. Steel Corp., a one-year term as Chairman of the ISD.

Nominations to The Metallurgical Society Nominating Committee from the Extractive Metallurgy Division are P. T. Stroup, Aluminum Company of America; J. H. Schloen, Canadian Copper Refiners Ltd.; and B. W. Gonser, Battelle Memorial Institute.

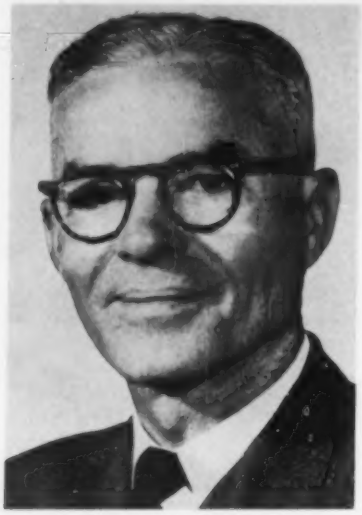
J. S. SMART, JR.

The Iron and Steel Division has nominated N. J. Grant, Massachusetts Institute of Technology, for a two-year term of office, and C. T. Marshall, Pittsburgh Coke and Chemical Co., a one-year term. J. S. Marsh, Bethlehem Steel Co., will complete the second of a two-year term on The Metallurgical Society Nominating Committee.

Nominations from the Institute of Metals Division will be published later.

For AIME nominations, turn the page.

Announce Nominations for AIME's 1960 Officers



R. R. McNAUGHTON

Ronald R. McNaughton has been nominated to serve as AIME President Elect, to assume the presidency in 1961. Nominated by The Metallurgical Society of the AIME, Mr. McNaughton will hold the office of President-Elect during 1960. The Society of Petroleum Engineers will nominate the 1962 president next year.

Mr. McNaughton is manager of the Metallurgical div. of The Consolidated Mining & Smelting Co. of Canada, Ltd. He has been employed by the company since graduation from McGill University. In the course of 35 years there he has risen from assistant foreman in the smelting dept. up the administrative ladder to his current post. Active in AIME activities for many years, Mr. McNaughton served as Chairman of the EMD in 1953. He was a Director of AIME that same year, and the year following.

Vice Presidents

John Chipman, head of the Dept. of Metallurgy at the Massachusetts Institute of Technology, has been nominated to serve a one-year term as Vice President of the AIME. His nomination by The Metallurgical Society comes on the heels of his current position as President of The Metallurgical Society for 1959.

Dr. Chipman has been active in both the metallurgy field and metallurgy societies for many years. His contributions to the education and literature of metallurgy are innumberable. He was also instrumental in the war effort, serving as chief of the Metallurgy Section of the Metallurgical Laboratory on the Manhatten Project in World War II. He has since worked on a number of Government scientific and technical committees.

Dr. Chipman is probably best known for his research concerning the role of oxygen in iron and steelmaking. He joined the faculty at MIT in 1937, and became the head of the metallurgy dept. in 1946.

His awards include: the *Robt. W. Hunt Medal* (AIME), the *Henry M. Howe Medal* (ASM), the *Henry Bessemer Medal* (UK), the *Losana Gold Medal* (Italy), the *John A. Brinell Medal* (Sweden), and has delivered The Howe Memorial Lecture, sponsored by the AIME.

In addition to his role as The Metallurgical Society's president, Dr. Chipman's AIME activities include the chairmanship of the Iron and Steel Div. in 1957, and committee member of the Physical Chemistry of Steelmaking and Publications committees.

Walter R. Hibbard, Jr., is the second nominee for Vice President of AIME as made by The Metallurgical Society. Dr. Hibbard, who brings with him a history of activity in the Institute, is currently manager of alloy studies research, at the General Electric research laboratory in Schenectady, N. Y.

Dr. Hibbard, the 1958 President of The Metallurgical Society, now holds the office of Past-President. Since joining the AIME in 1940, he has also served as Chairman of the IMD (1957), and as member of the Programs Committee, the Mathewson Gold Medal Committee, the Publications Committee, and the Executive Committee. He is also the 1950 winner of the AIME-sponsored *Rossiter W. Raymond Memorial Award* for the best paper published by a member under 33 years of age.

Stanley D. Michaelson, 1958 President of the Society of Mining Engineers, has been nominated to a one-year term as Vice President on the AIME. The SME nominee is chief engineer of Western Mining Div., Kennecott Copper Corp. An active AIME member, Mr. Michaelson served as Chairman of the Mining Board of Directors in 1954, and was elected Director of the Institute that same year.

One of the highlights of Mr. Michaelson's career was his association with the Tennessee Coal & Iron Div. of U. S. Steel Corp. There he completed a 20,000-tpd Concord mine project—marking the first integration of rock bolting in a mining scheme as a regular production tool.

J. W. Woomer, current president of the Society of Mining Engineers, is the Society's second nomination as Vice President to the AIME. His one-year term will begin in February, 1960. Head of his own consulting firm, J. W. Woomer & Associates, Mr. Woomer has worked at all levels of the mining industry. The experience is marked by an equal range in geography with assignments in Alaska, Argentina, Australia, Canada, Chile, China, Columbia, France, Germany, Greece, India, Manchuria, Mexico, Turkey, and the United Kingdom.

Long a member of the AIME Coal Division, Mr. Woomer was its 1958

JOHN CHIPMAN

W. R. HIBBARD, JR.

S. D. MICHAELSON

chairman. He is also director of the Engineering Society of Western Pennsylvania, and is a member of several other mining societies.

Basil P. Kantzer, 1958 President of the Society of Petroleum Engineers, is one of the Society's two vice presidential nominees to the AIME. Mr. Kantzer, who is now a member of the AIME Board of Directors, is himself a vice president of Union Oil Co. of California. Mr. Kantzer's other offices have included the chairmanship of the Pacific Petroleum Chapter and Southern California Petroleum section of AIME. He was Petroleum Branch chairman in 1953.

John P. Hammond is the second SPE candidate for AIME vice president. Mr. Hammond, who is currently a member of the AIME Board of Directors, was the 1957 President of the Society of Petroleum Engineers. Professionally, he is assistant general supt. of the Production Dept., Amerada Petroleum Corp., Tulsa. He has formerly served as Petroleum Branch vice-chairman, Publications Committee chairman, Mid-Continent Local section chairman, and in other capacities for the SPE.

Directors

J. S. Smart, Jr., in addition to being nominated as President Elect of The Metallurgical Society, has also been named as a Director on the AIME Board of Directors. His three-year term of office will begin in February, 1960. Before assuming his present position as general sales manager at the American Smelting & Refining Co., Mr. Smart was active in metallurgy research. Copper metallurgy and continuous casting were his main interests, and he was the innovator of several now patented continuous casting processes. He is also internationally known as an authority on the properties and treatment of copper.

Active in the AIME for many years, Mr. Smart also served as a Director in 1955. He was also chairman of the Rossiter W. Raymond Award Committee in 1954. In 1948 he was himself the recipient of the *IMD Award*, now the *Mathewson Gold Medal*.

James B. Austin is the second member of The Metallurgical Society to be nominated to the AIME's Board of Directors for a three-year term. Dr. Austin is vice president in charge of research and technology, U. S. Steel Corp. He has been with U. S. Steel for 31 years, having joined them in 1928 after receiving his Ph.D. in physical chemistry from Yale. An AIME member since 1944, Dr. Austin's activities include membership on the IMD Executive Committee. He is also a past president of the American Society for Metals.

R. H. Feierabend has received nomination by the Society of Mining Engineers to serve a three-year term as an AIME Director. Mr. Feierabend, assistant vice president of the Freeport Sulphur Co., has been active in both the Mining and Exploration and Industrial Minerals Divisions of the SME.

James C. Gray is the second nomination to the AIME's Board of Directors by the Society of Mining Engineers. Mr. Gray is Administrative Vice President for Raw materials of the Tennessee Coal & Iron div. of U. S. Steel Corp. Mr. Gray has been active in the AIME, including memberships on the Executive Committee and past chairman of the Southeast section.

Herbert F. Beardmore is the Society of Petroleum Engineers nomination to the AIME Board of Directors. Mr. Beardmore, who will begin his three-year term of office in February, 1960, is manager of Gulf Oil Corp.'s Gulf Coast District in Houston. Prior to Warren Petroleum Corp.'s merger with Gulf, he was a vice president there.

A second director, who will also assume the position of President-

JAMES B. AUSTIN

R. H. FEIERABEND

JAMES C. GRAY

J. W. WOOMER

B. P. KANTZER

J. P. HAMMOND

Directors . . .

(Continued from page 473)

H. F. BEARDMORE

Elect, will be named in October.

In addition to the incoming officers and directors listed on the preceding pages, the following individuals, now on the Board, will serve in these capacities after the Annual Meeting in February, 1960:

President of AIME for 1960, Joseph L. Gillson.

Past-President for 1960, Howard C. Pyle.

AIME Directors for 1960, J. C. Kinnear, Jr. and C. C. Long of The Metallurgical Society; A. B. Cummins, Society of Mining Engineers; and John S. Bell, Wayne E. Glenn, Society of Petroleum Engineers.

Fall Meeting to Take Up Physical, Extractive Metallurgy

The Fall Meeting of the Metallurgical Society will feature a comprehensive program dealing with the fields of physical and extractive metallurgy Nov. 2-5 at the Hotel Morrison, Chicago. The Fall Meeting, sponsored by the Institute of Metals Division, is held annually during the Metal Congress.

The Division's Committee on the Chemistry and Physics of Metals is planning two sessions for the mornings of Nov. 2nd and 3rd. Monday, Nov. 2nd, will also feature two Refractory Metals Committee sessions on the *Preparation of Refractory Metals and Their Properties.*

Then, on Tuesday, Nov. 3rd, sessions on the *Extractive Metallugry of Refractory Metals,* and the *Refining of Pure Metals,* organized by the Extractive Metallurgy Division, will supplement the IMD's program. The Iron and Steel Division has also been allotted two sessions on Tuesday for papers on current development in steelmaking. The Titanium Committee's annual symposium on titanium developments will also be presented on Tuesday. And that evening the Annual Fellowship dinner will take place in the Hotel.

On Wednesday, Nov. 4th, the Nuclear Metallurgy Committee will conduct an all-day symposium on the *Effects of Irradiation on Fuels and Fuel Elements.* Then, on Thursday, Nov. 5th, the Powder Metallurgy Committee has reserved two sessions. That day will also witness the Non-Ferrous Metallurgy Committee's two sessions on *Current Practices in the Melting and Casting of Non-Ferrous Alloys.*

Cleveland to Host Electric Furnace Men

Cleveland will be the site of the 1959 Electric Furnace Conference, Dec. 2-4. It marks the first time since 1945 that the city has been host to the Conference.

Departing from the usual custom, the technical sessions will be held on the first two days (Wednesday and Thursday) in the Cleveland Hotel, and the plant trips on the last day, Friday. Arrangements have been made for plant trips to Republic Steel Corp., Canton, Ohio; and Babcock & Wilcox Co., Barberton, Ohio. The Annual Dinner will be held on Thursday evening, December 3rd.

Technical sessions are planned on Arc Characteristics . . . Refractories . . . Raw Materials and Special Alloys . . . Construction Steels . . . Tool Steels . . . Stainless Steels . . . Electrode Penetration . . . Automatic Furnace Regulation . . . and the Manufacture of Calcium Carbide and Refractories.

The technical program is being organized under the supervision of A. C. Ogan, chairman of the Executive committee, and P. R. Gouwens, chairman of the conference committee, assisted by G. C. Olson and R. K. Kulp. W. M. Charman, Jr., is chairman of the committee on local arrangements.

AROUND THE SECTIONS

The May 6th meeting of the **Lima, Peru** section featured a surprise cocktail party for Mr. and Mrs. Walter King. Mr. King is the secretary of the section, and members gathered to toast them on the eve of their leaving for a vacation in England.

Western section's steel committee heard John Golden, chairman of the operating committee, steel production, U. S. Steel Corp., speak on *Basic Roofs on Open Hearth Furnaces* at its May 14th meeting in Los Angeles. The social hour and dinner was the last one of the season for the steel men.

Colorado section called for contributions to the AIME's United Engineering Building at its April 16th dinner meeting in Denver. Chairman William L. Miles, Jr., urged members to contribute "at least $20" over a three-year period toward the building fund. He pointed out that the building is essential to the successful operation of the institute, and is for the good of everyone. Following the business portion of the meeting, members listened to V. E. Wessels, of the Ideal Cement Co., who spoke on the history and uses of Ideal's cement products.

Pennsylvania-Anthracite section held its Annual Summer Meeting on June 24th. Guests of honor at the meeting were President and Mrs. Howard C. Pyle of the AIME. Golf matches, prizes, dinner, and cocktails were featured attractions at the Irem Temple Country Club meeting in Dallas, Pa.

New York section conducted a plant trip to the Anaconda Wire and Cable Company at Hastings, N. Y. on May 22. Facilities visited included the rod mill, wire mill, cable mill, new high voltage cable facilities, telephone cable department, plastics insulation department, and the new 3,000,000-v laboratory.

An all-day outing provided the setting for the **Adirondack** section's May 23rd meeting. Included in the day was buffet luncheon, an underground tour of a mine at Mineville, Pa., a golf tourney, a roast beef dinner, and a brief business meeting. At the business meeting members were again reminded of the need for contributions to the United Engineering Center. The Section has set itself a goal of $1500 toward the project.

Morenci sub-section of the Arizon section heard Linton Claridge of Safford, Ariz., speak on his recent trip to Russia at its May 12th meeting. The talk, illustrated with slide pictures, was given at the Longfellow Inn in Morenci, Ariz. The group's next scheduled meeting will be Sept. 8th; plans for that meeting are incomplete.

Semiconductors Men Convene in Boston Aug. 31-Sept. 2

With the program now in finalized form, the technical conference on Properties of Elemental and Compound Semiconductors promises to be of international interest to metallurgists and others working with these materials. The meeting, sponsored by the IMD Semiconductors Committee, will be held at the Statler Hotel in Boston Aug. 31-Sept. 2.

Technical sessions on Monday, Aug. 31st, and Tuesday, Sept. 1st, will be nearly equally divided between invited and contributed papers. Wednesday, Sept. 2nd, will be devoted to a visit to MIT's Lincoln Laboratory, currently undertaking work in radar, memory devices, transistorized digital computors, SAGE, and the solid state.

In order to insure ample opportunity for informal discussion, the Semiconductors Committee has limited non-technical activities to a social hour Monday evening, followed by a Fellowship Dinner.

Registration fee for the 3-day meeting is $10 to AIME members; $15 for non-members. The fee entitles registrants to a Proceedings volume containing papers as well as discussion given at the meeting. The material will be automatically sent to all registrants.

Registration information and forms may be obtained from *W. C. Hittinger, 555 Union Blvd., Allentown, Pa.* Mr. Hittinger is Chairman of the Semiconductors Committee, which is sponsoring the Conference with the Boston section of the AIME. The technical program appears below.

MONDAY, AUGUST 31

8:30 a.m. to 4:00 p.m. Registration, Mezzanine

9:15 a.m. to 12:30 p.m. Session I

Please Note
All sessions will be held in Parlor B, Mezzanine Floor.

Opening remarks by W. C. Hittinger, Chairman, Semiconductors Committee

Defect Interactions in Semiconductors, H. Reiss and W. Kaiser, Bell Telephone Laboratories, Murray Hill, N. J.

Semiconductor Surfaces and Films, M.M. Atalla, Bell Telephone Laboratories, Murray Hill, N. J.

Dislocations in Semiconductors, W. C. Dash, General Electric Co., Schenectady, N. Y.

Distribution Coefficients in Germanium and Silicon, C. D. Thurmond, Bell Telephone Laboratories, Murray Hill, N. J.

2:00 p.m. to 5:30 p.m. Session II

Role of Dislocations in Device Properties, L. E. Miller, Bell Telephone Laboratories, Laureldale, Pa.

Panel Discussion: The Role of Dislocations in Device Properties

Panel Members: C. W. Mueller, Radio Corp. of America, Princeton, N. J.; W. C. Dash, General Electric Co., Schenectady, N. Y.; L. E. Miller, Bell Telephone Laboratories, Laureldale, Pa.; W. E. Taylor, Motorola, Inc., Phoenix, Ariz.; and W. A. Adcock, Texas Instruments, Inc., Dallas, Texas

Experimental Results with Large-Area Floating Zones, K. E. Benson and W. G. Pfann, Bell Telephone Laboratories, Murray Hill, N. J.

Effect of Elastic Strain on the Anomalous Transmission of X-rays in Germanium, G. E. Brock, International Business Machines Corp., Poughkeepsie, N. Y.

Distribution Coefficients of Impurities in Gallium Arsenide, J. M. Whelan, J. D. Struthers, and J. A. Ditzenberger, Bell Telephone Laboratories, Murray Hill, N. J.

Efficiency of Zone-Refining Processes, L. W. Davies, Bell Telephone Laboratories, Murray Hill, N. J.

6:00 p.m. Cocktail hour for Holders of Dinner Tickets

7:00 p.m. Fellowship Dinner

TUESDAY, SEPTEMBER 1

9:00 a.m. to 4:00 p.m. Registration

9:00 a.m. to 12:00 m. Session III

Stoichiometry in Compound Semicondutors, W. W. Scanlon, Naval Ordnance Laboratory, Silver Springs, Md.

Properties of Silicon Carbide and Gallium Phosphide for Power Rectification, R. Davis, Westinghouse Electric Corp., Wilkinsburg, Pa.

Materials Research on Gallium Arsenide and Indium Phosphide for High-Temperature Transistors, L. Weisberg and F. D. Rosi, Radio Corp. of America, Princeton, N. J.

Metallurgy of Some Ternary Semiconductor Compounds, J. H. Wernick, Bell Telephone Laboratories, Murray Hill, N. J.

Materials for Thermoelectric Applications, R. W. Ure, Jr., R. Bowers, and R. C. Miller, Westinghouse Electric Corp., Pittsburgh, Pa.

2:00 to 5:00 p.m. Session IV

Use of the Electron Probe X-ray Micro-analyzer in the Study of Semiconductor Alloys, J. M. Axelrod and D. B. Wittry, Hughes Aircraft Co., Los Angeles, Calif.

Etch Pits, Dislocations, and Deformation in Gallium Arsenide, M. S. Abrahams and L. Ekstrom, Radio Corp. of America, Princeton, N. J.

Electrical and Thermal Properties of Some Silicides, S. E. Mayer and A. I. Mlavsky, Transitron Electric Corp., Wakefield, Mass.

Diffusion of Zinc in Indium Antimonide, B. Goldstein, Radio Corp. of America, Princeton, N.J.

Thermoelectric Properties of Pressed Bismuth Telluride Powders, C. Kolm and J. J. Giacalone, Massachusetts Institute of Technology, Lexington, Mass.

Thermal, Electrical, and Optical Properties of (Indium, Gallium) Arsenide Alloys, M. S. Abrahams, R. Braunstein, and F. D. Rosi, Radio Corp. of America, Princeton, N. J.

WEDNESDAY, SEPTEMBER 2

9:00 a.m. Laboratory Visit

Tour of Lincoln Laboratory, Bedford, Mass. (Return to Statler Hotel, Boston, by 12:30 p.m.)

Last Call -

Abstract Deadline July 15

The deadline date for submission of abstracts for IMD sessions at the Fall Meeting of The Metallurgical Society, November 2-5, Morrison Hotel, Chicago, Ill., is **July 15, 1959.** The abstracts should be between 200 to 300 words, and should be submitted in three (3) copies to:

IMD Programs Committee
The Metallurgical Society of AIME
29 West 39th Street
New York 18, N. Y.

(No photographs, diagrams, or tables should be included.)

Society Directories Now Available

The Metallurgical Society's 1959 Directory appears as an insert in this issue of JOURNAL OF METALS. Extra copies of the Directory are available at $1 per copy through the AIME Order Department, 29 W. 39th St., NYC.

Directories for the Society of Mining Engineers and Society of Petroleum Engineers are also off the press and available to all members. Directories for these societies are also available from the Order Department at $1 each.

To make better use of the Directories, a binder may be purchased through the AIME for $2.50. A special price of $5 is offered AIME members for the binder, plus the three society Directories. Nonmembers can get the same materials for $5.50.

The next Directory of The Metallurgical Society's members is planned for July, 1961. Directories for the other two societies are planned on a yearly basis.

EJC Takes Over Student Exchange Plan (IAESTE)

EJC has taken over the administration of the International Association for the Exchange of Students for Technical Experience (IAESTE). The 24-member country organization places engineering and science students with foreign industrial firms. The IAESTE program is now integrated with the EJC International Relations Committee, headquartered at 29 W. 39th St., NYC.

MEMBERSHIP

Proposed for Membership
Metallurgical Society of AIME

Total AIME membership on May 1, 1959 was 31,653; in addition 2,412 Student members were enrolled.

ADMISSIONS COMMITTEE

L. L. Seigle, Chairman; W. L. Brytczuk; F. B. Foley; T. D. Jones; Harold Margolin; Shadburn Marshall.

The Institute desires to extend its privileges to every person to whom it can be of service, but does not desire as members persons who are unqualified. Institute members are urged to review this list as soon as possible and immediately to inform the Secretary's office if names of people are found who are known to be unqualified for AIME membership.

Members

Adamec, John, Closter, N.J.
Allan, James T., Peekskill, N.Y.
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Mead, Harry L., Prairie Village, Kans.
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Oswald, Richard E., St. Louis, Mo.
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Watt, Charles E., Greenburg, Pa.
Winters, William G., Cleveland, Ohio
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Smeltzer, Charles E., Jr., Reading, Pa.
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Webster, Arthur H., Ottawa, Canada

CHANGE OF STATUS

Associate to Member

Hinds, Gene W., Westfield, N.J.
Tauscher, Joseph E., Gresham, Ore.

REINSTATEMENTS

Member

Matthews, Norman A., Detroit, Mich.

Associate

Anderson, William E., Seattle, Wash.
Butt, Corienne E., Milwaukee, Wisc.
Osadchuk, R., Toronto, Canada

Junior

Lindemer, Terrence, Lowell, Ind.

REINSTATEMENTS—CHANGE OF STATUS

Student to Member

Misencik, John A., Bolton, Mass.

RE-ELECTION

Minor, James E., Richland, Wash.

OBITUARIES

Marvin J. Udy

An Appreciation by

O. C. Ralston

Death at age 67 in modern times is untimely for a man of normal vigorous health and good habits. Marvin Udy, Vice President and Consultant for Strategic-Udy Processes, Inc., was such a man. He was an able and serious man, born on a Utah farm Feb. 19, 1892. From that beginning, every step up the ladder of career success was richly deserved, and those who came to know him well trusted and admired him.

I first met Udy at the University of Utah in 1914. It was here, too, that Udy had gained honors, both for his scholastic and baseball ability.

I came there because the Bureau of Mines, with which I was working, was invited to use the University's Mining Building for an experimental station. The state of Utah had just established five fellowships to encourage graduate

work in the mineral industry. The fellows were to carry on their research projects in the experimental station, and I was chosen as their team leader. Marvin Udy was one of the fellows, and he, together with Wallace G. Woolf, were the two star performers. Both gained their masters degrees in one year.

Marvin was entranced with metallurgical research, and applied for a second year on the fellowship. During the second year, Glen L. Allen was a teammate who studied flotation of oxidized lead ores. Udy put in much of his time on hydrometallurgy of the same types of ores. After competing his studies, Udy went to U. S. Mining & Concentrating Co., at Midvale, Utah, to do research and development work on cadmium recovery from flue dusts. There he learned much about electrolytic cadmium deposition, and also shared in testing of electrolytic zinc recovery from such residues. However, the project was dropped because of the scale of operation needed when working with a low-priced commodity like zinc. While at Midvale, a bismuth recovery process was patented in his name.

About the same time, I went to Niagara Falls with Hooker Electrochemical Co. (now Hooker Chemical Co.), to lead a team investigating metallurgical uses of chlorine. One proposed use was to produce zinc chloride for hard fibre products and timber preservation. All of the flue dusts and scrap zinc available contained cadmium; therefore, I sent for Udy and another fellowship man, Clyde E. Williams.

Udy was assigned the cadmium problem first, and very quickly disposed of it. A second problem was the separation of cobalt and nickel by a modified chlorine-calcium process. This too was solved and patented. It was at this time that Elwood Haynes, inventor of the Stellite series of cobalt alloys, visited Niagara Falls. The process was demonstrated to him, together with the chlorination of sulfarsenide ores from the Cobalt, Ontario area.

Then, the area's silver was in demand, but the cobalt, nickel, and arsenic contents were only a cause of difficulty. Haynes bought the patent, but also needed Udy, and made an attractive offer. I recommended that Udy ask for a mere living wage and a percentage of the profits. I understood that he left for Kokomo, Ind., with Haynes under that stipulation.

Baseball should be mentioned, however, before we forget Niagara Falls. When Udy was first employed by Hooker, the interplant baseball leagues of Niagara Falls was very active. Hooker had few pitchers, and wallowed in the league standings. The baseball manager quizzed me about Udy and I told him that his record at the University of Utah was good. He persuaded Udy to give his batters some good pitching, and finally managed to get him to pitch a game. It was a shut out. Udy hated to give time to baseball, but he was trapped. The Hooker team cleaned up on the rest of the league, and Udy became a famous person around town. Few hard-working, serious fellows are fated to make such records.

Moving the scene from Niagara Falls to Kokomo, the Stellite Corp. prospered greatly with Udy. While there, he helped a neighbor with a problem of a non rust-resistant piano wire; he plated it with cadmium. Based on this venture, the Stellite Corp. grew into a series of electroplating processes. For years it has had a place on the New York Stock Exchange. Haynes later sold the Stellite enterprise to Electrometallurgical Co. (div. of Union Carbide) for a reported $5 million, and Udy went with the Stellite assets.

He next pursued chromium plating, being an early patentee in it. In 1932, during the depression, he left Electrometallurgical and began to study exothermic mixtures of chrome ore and ferroalloys like ferrosilicon. He wanted to find out how a small foundry could add chromium to a batch of iron alloy to create an exothermic mix. It was thus that Chrome-X was born. It was a very important invention; Man-X and Sil-X were also contemplated, but Chrome-X made Udy famous.

Leo Timmons, of Ontario, Canada, took an interest in Udy's ideas on chromium technology and founded Chromium Mining & Smelting Co., Ltd., based on an electric smelting plant at Sault Ste Marie, Ont. Udy was made Vice President. During World War II, the company expanded into the US. Udy created a research and development division and became its consultant. There he gained the reputation of being the best electric furnace man not in the employ of a steelmaker.

Research in selective reduction of unwanted iron led to the next and final chapter in Udy's life. Ores of chromium, manganese, titanium, and other metals are often too high in iron to be marketable. When Udy developed a reduction system for producing a high grade material for smelting into acceptable products, it led to the formation of the Strategic Materials Co., Ltd., later called Strategic-Udy Processes, Inc., with Udy as Vice President. This was his most active enterprise, and the one with which he died on April 11th.

Marvin Udy was married when he graduated from the University of Utah, and his first son, Murray C. Udy, was born during his post graduate work. A second son, Lynn, died in maturity. Murray spent many years at the Battelle Institute before he joined forces with his father and began taking an increasing share of the burden in the partnership. Fortunately Marvin's work has been organized to carry on, but nonetheless, the world is impoverished by the loss of this talented metallurgist.

Loyal G. Tinkler (member 1936) died on May 7, 1958. Mr. Tinkler, a former metallurgical engineer for the Vanadium Corp. of America, retired only last year. He graduated from Cornell University in 1915, and received a masters degree in physical chemistry from Brooklyn Polytechnic Institute in 1935.

NECROLOGY

Date Elected	Name	Date of Death
1946	Banks, H. Raymond	Feb. 4, 1959
1945	Falconer, Stuart A.	Apr. 25, 1959
1951	Freehling, Robert N.	Apr. 3, 1959
1946	Hefferan, Jaun V.	Apr. 24, 1959
1957	Henderson, Lawrence	Apr. 24, 1959
1957	Holland, George T.	Oct. 10, 1958
1954	Legge, Theo. Worley	March 1959
1959	Luckett, Joseph S.	Mar. 30, 1959
1930	Robbins, James S.	Dec. 7, 1958
1936	Tinkler, Loyal G.	May 7, 1959
1918	Udy, Marvin J.	Apr. 11, 1959
1940	Van Dyke, W. D., Jr.	Apr. 29, 1959
1953	Woodman, Frank W.	Mar. 15, 1959
1918	Young, Edward L.	May 6, 1959

PROFESSIONAL SERVICES

Limited to AIME members, or to companies that have at least one AIME member on their staffs. Rates $50 per year per inch.

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Coming Events

Aug. 23-25, Conference on the Fracture of Engineering Materials (ASM), Rensselaer Polytechnic Institute, Troy, N.Y.

Aug. 31-Sept. 2, AIME Semiconductors Conference, Statler Hotel, Boston, Mass.

Sept. 10, AIME, NOHC Chicago Section, Golf Party and Dinner, Midlothian Country Club, Chicago.

Sept. 18-19, Seventh Engineering Management Conference co-sponsored by The Metallugical Society of AIME, ASME, AIEE, and others. Hotel Statler, Los Angeles.

Sept. 21-22, 57th Fall meeting of the Steel Founders' Society of America, at the Homestead, Hot Springs, Va.

Oct. 5, AIME, NOHC Chicago Section Fall Dinner Meeting, Phil Smidt's Restaurant, Hammond, Ind.

Oct. 7-9, Sixth National Symposium on Vacuum Technology of the American Vacuum Society, Sheraton Hotel, Philadelphia.

Oct. 8-9, AIME, NOHC Southwestern Section, Fall Meeting, Pere Marquette Hotel, Peoria, Ill.

Oct. 9, AIME, NOHC Eastern Section, 13th Annual Conference, Warwick Hotel, Philadelphia.

Oct. 16-17, AIME, NOHC Southern Ohio Section, Fall Meeting, Deshler-Hilton Hotel, Columbus, Ohio.

Nov. 2-5, Fall Meeting of The Metallurgical Society of AIME, Morrison Hotel, Chicago.

Nov. 6, AIME, NOHC Pittsburgh Section, Off-the-Record Meeting, Penn-Sheraton Hotel, Pittsburgh.

Nov. 10, AIME, NOHC Buffalo Section, 10th Annual Meeting, Royal Connaught Hotel, Hamilton, Ontario, Canada.

Nov. 16-20, Conference on Magnetism and Magnetic Materials, Sheraton Hotel, Philadelphia.

Dec. 2-4, AIME 17th Electric Furnace Steel Conference, Hotel Cleveland, Cleveland, Ohio.

Feb. 14-18, 1960, AIME Annual Meeting, Hotel McAlpin and Hotel Statler, New York.

Feb. 16-19, 1960, Symposium on Hydrometallurgy, *Wet Processing of Minerals and Industrial Products,* The Australasian Institute of Mining & Metallurgy, Adelaide, Australia.

Mar. 15-21, 1960, Third International Conference on Nondestructive Testing, Tokyo, Mar. 15-18; Osaka, Mar. 21.

Apr. 4-6, 1960, AIME 43rd National Open Hearth Steel Conference and Blast Furnace, Coke Oven, and Raw Materials Conference, Palmer House, Chicago.

Apr. 21-22, 1960, Southwest Metals and Minerals Conference, Ambassador Hotel, Los Angeles, Calif.

June 13-15, 1960, first International Powder Metallurgy Conference, Hotel Biltmore, New York, under joint auspices of AIME and MPI.

Oct. 17-21, 1960, Fall Meeting of The Metallurgical Society of AIME, Sheraton Hotel, Philadelphia.

Nov. 4, 1960, AIME, NOHC Pittsburgh Section, NOHC, Off-the-Record Meeting.

Nov. 30-Dec. 2, 1960, AIME 18th Electric Furnace Steel Conference, Morrison Hotel, Chicago.

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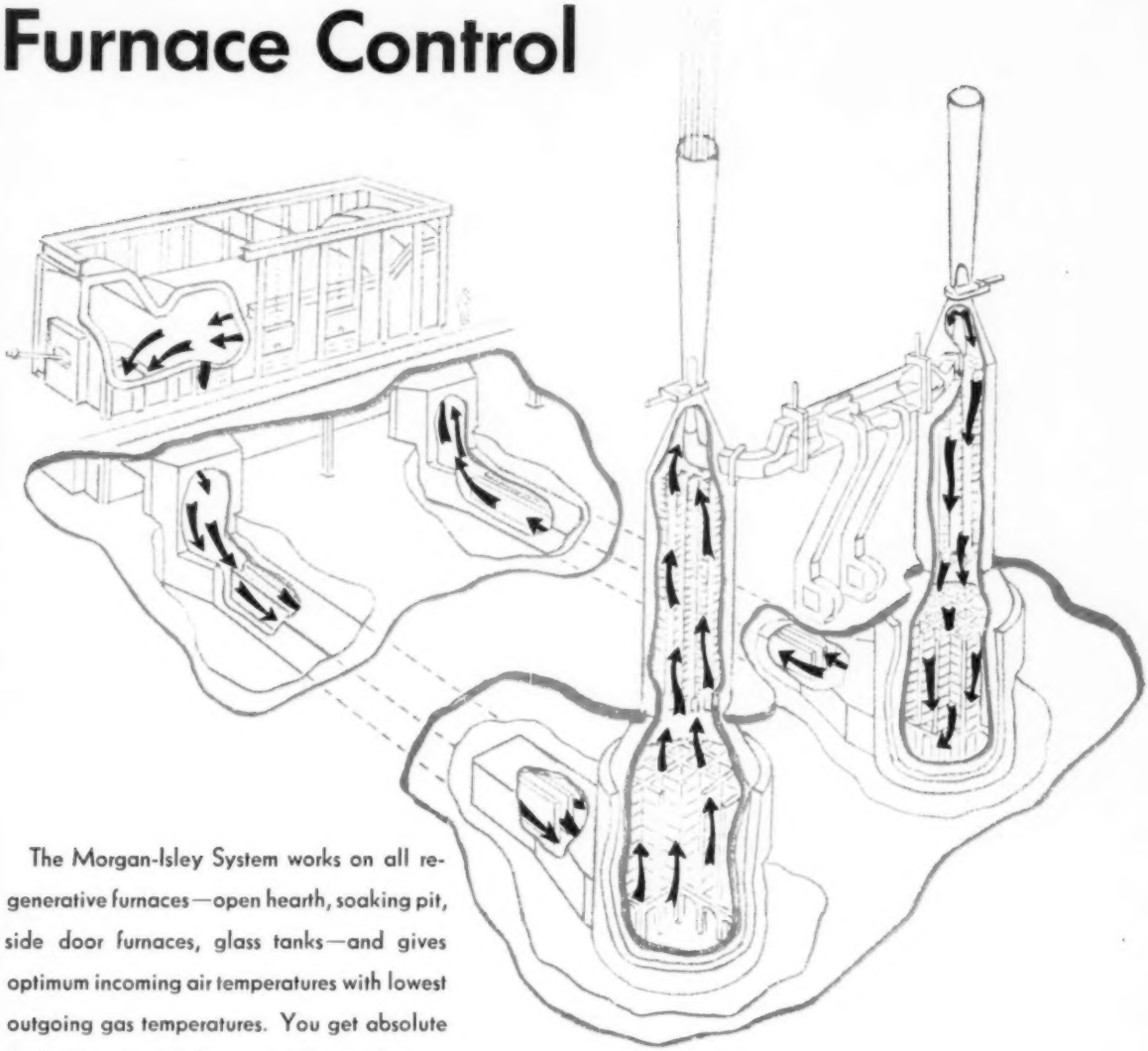

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